APR 7 1952

524

SER. II, VOL. 14 *December, 1951* NO. 2

(COPY 2)

TRANSACTIONS
OF
THE NEW YORK ACADEMY OF SCIENCES

Editor
ROY WALDO MINER

Associate Editor
JAMES A. GOODE

Contents

Elasticity and Constitution of the Earth's Interior. *By* FRANCIS BIRCH 72
Symposium on Intravenous Lipid Emulsions:
Intravenous Lipid Emulsions. *By* E. D. GOLDSMITH 77
Clinical Studies on Hepatic Function Following Administration of Intravenous Fat Emulsions. *By* W. B. WADDELL, T. B. VAN ITALLIE, R. P. GEYER, AND F. J. STARE 78
The Administration of Fat Emulsions in Man. *By* B. G. P. SHAFIROFF 80
The Localization of Particulate Fat in Injured Blood Vessels. *By* W. B. MCALLISTER AND L. L. WATERS 83
Problems in the Provision of Calories Parenterally. *By* SIDNEY C. WERNER 84
Aero-thermodynamic Phenomena in a Revolving Fluid Motion. *By* PAUL H. SAVET .. 86
Reading and Visual Work: A Contribution to the Technique of Experimentation on Human Fatigue. *By* LEONARD CARMICHAEL 94
Studies on Lignin and Lignification. *By* F. F. NORD AND GEORGE DE STEVENS 97
The Isolation of Plant Rusts Upon Artificial Media and Some Speculation on the Metabolism of Obligate Plant Parasites. *By* VICTOR M. CUTTER, JR. 103
Philosophical Anthropology and World Law. *By* F. S. C. NORTHROP 109
The General Circulation of the Lower Atmosphere. *By* SVERRE PETTERSSEN 113
Conferences Held 120
New Members 123

Copyright, 1951, by The New York Academy of Sciences

TRANSACTIONS of The New York Academy of Sciences, Series II, Volume 14, No. 2, December, 1951.

Entered as second-class matter December 12, 1947, at the post office at Baltimore, Maryland, under the act of August 24, 1912. This publication is distributed to members and is published monthly from November to June, inclusive, by The New York Academy of Sciences, Mt. Royal and Guilford Aves., Baltimore 2, Md. Editorial office: 2 East Sixty-third Street, New York 21, New York.

Executive Director: EUNICE THOMAS MINER

SECTION OF GEOLOGY AND MINERALOGY

ELASTICITY AND CONSTITUTION OF THE EARTH'S INTERIOR*

By FRANCIS BIRCH†

Probably most of us are skeptical about the possibility of arriving at very definite conclusions on a subject which offers so few avenues of approach, and involves conditions so far from those of ordinary experience. I believe, however, that we are on the threshold of new advances in the problem of the Earth's interior, through a combination of experiment and theory which gives us a clearer understanding of the physical basis of seismology, the elasticity of condensed phases of matter.

Two fundamental facts were established during the "astronomical" period of geophysics: (1) with the determination of the constant of universal gravitation, and the determination of the dimensions of the Earth, the mean density was found to be 5.52 (most ordinary rocks have densities between 2 and 3) and (2) by a combination of astronomical and geodetic measurements, the moment of inertia about the axis of rotation was found to be only $\frac{4}{10}$ as great as the moment for a sphere of the same size and mass, with uniform density. It has long been clear, therefore, that there must be a higher density near the center than in the outer parts. The two conditions of density distribution have been the starting point in many attempts to determine the whole course of variation of density.

Dana (1873) and Wiechert (1897) arrived at the conception of a core of high density surrounded by a shell of lower density. This model was suggested by the most striking fact concerning meteorites, *i.e.*, that they are composed chiefly of two distinctly different materials: silicates and metallic iron. Wiechert's calculations were based on a central core of uniform density approximating that of iron, and a rocky shell, with a uniform density approximating that of the heaviest known rocks. In broad outline, no better solution has yet been found, though we are now able to improve greatly upon the details.

Around 1900, the development of instrumental seismology began to produce, for the first time, facts related to definite levels inside the Earth. Seismology depends upon the fact that an earthquake, no matter where it originates, creates a mechanical disturbance everywhere else on Earth We interpret this fact in terms of the propagation of elastic waves from the source to the point of reception, and the study of their times of arrival at various distances leads to a determination of the velocity of propagation as function of the depth, or radius.

The principal facts are (1) the existence to a depth of 2900 km of two modes of propagation of elastic waves, with distinct velocities, called V_P for waves of compression, V_S for waves of rotation or shear; and (2) a discontinuity of velocity and the disappearance of one mode at this depth of 2900 km. Studies of waves which have passed close to the depth of 2900 km indicate that the discontinuity is sharp, in the physical sense that its spread is a small fraction of a wave-length. This discontinuity is the best-established detail regarding the interior of the Earth, and leads to the major division between "mantle" and "core." The single velocity within the core is identified with the velocity V_P of compressional waves, and the absence of V_S is the principal reason for supposing that most of the core is liquid, devoid of rigidity. This conclusion is supported by the studies of earth tides and the variation of latitude.

The discovery of the major seismic discontinuity by Oldham, and subsequent accurate determinations of its depth by Gutenberg and Jeffreys, gave physical reality to Wiechert's picture, though greatly changing his point of division. At the same time, the development of the data shown in FIGURE 1 made it possible to consider a point neglected by Wiechert, *i.e.*, the effect of pressure in changing the density. L. H. Adams and E. D. Williamson of the Geophysical Laboratory in Washington noticed in 1923 that the seismic velocities could be used to determine the compressibility, or more precisely, the product of compressibility and density. This leads to a method, which Adams and Williamson were the first to apply, for using the seismic velocities to improve upon the crude density distribution proposed by Wiechert. The most recent work of

* Paper No. 129, published under the auspices of the Committee on Experimental Geology and Geophysics and the Division of Geological Sciences at Harvard University. This paper, illustrated with latern slides, was presented at the meeting of the Section on November 5, 1951.

† Harvard University, Cambridge, Mass.

this kind is by Bullen, who has used Jeffreys' velocities to obtain the distribution of density, and thence of acceleration and pressure, throughout the interior (FIGURE 2). These important results probably represent our closest approach to the correct variations of these quantities, and they are sufficiently exact for many purposes.

Implicit in the Adams-Williamson equation are certain assumptions about the change of density: (1) the change of density is assumed to be the result of compression alone, no change of material being allowed for; and (2) the compression is assumed to be adiabatic. The next improvement which we can hope to introduce, therefore, is to discover which regions, if any, are homogeneous in this sense, and to what extent the change of temperature with depth departs from the adiabatic relation. The published variations of density with depth are of course useless for this purpose, as they are based on the assumptions which we wish to test, and it becomes necessary to re-examine the primary data, the seismic velocities. As it turns out, it is most satisfactory to deal with the quantity denoted by ϕ, given by $V_P^2 - \frac{4}{3} V_S^2$.

On the other hand, we can write, on purely thermodynamical grounds, an expression for the rate of change of ϕ with radius in a uniform gravitating layer in which there is an arbitrary gradient of temperature. This is as follows: $1 - g^{-1} d\phi/dr = (\partial K_T/\partial P)_T +$ terms proportional to temperature and to the excess of temperature gradient above the adiabatic gradient. These terms involve the thermal expansion α, and such quantities as

$$\alpha^{-1} K_T^{-1} (\partial K_T/\partial T)_P, \quad \alpha^{-2} (\partial \alpha/\partial T)_P \text{ and } \alpha^{-1} C_P^{-1} (\partial C_P/\partial T)_P;$$

where K_T is the isothermal incompressibility, and

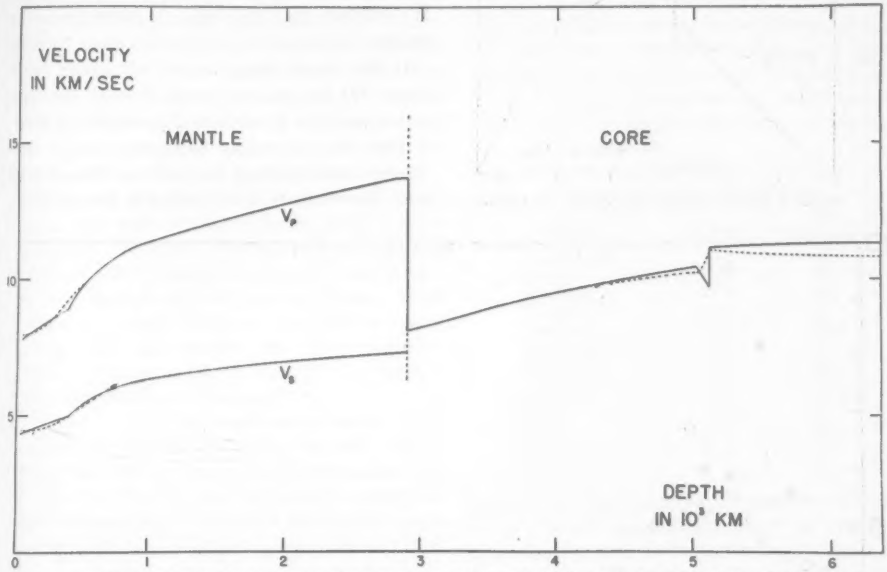


FIGURE 1. Velocities in the interior of the Earth, after Jeffreys (solid line) and Gutenberg (broken line).

C_P the specific heat at constant pressure. This expression shows us what quantities determine this variation. These are all non-dimensional parameters familiar in the theory of solids; $(\partial K_T/\partial P)_T$, the change of incompressibility with pressure, is the main term, the others amounting to corrections.

The further development of this approach, then, consists of the following steps: first, we must demonstrate, by a review of the experimental evidence, that the parameters of this equation for a uniform layer have characteristic values which are largely independent of the nature of the material, pressure, and temperature. These typical values are used to calculate an expected rate of variation of ϕ with depth; this normal rate can

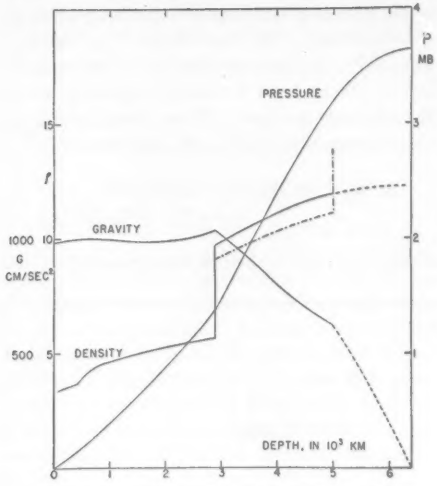


FIGURE 2. Density, gravity, and pressure, after Bullen.

for the mantle, the open circles from Jeffreys' velocities, the solid dots from Gutenberg's are plotted in FIGURE 3. The smooth curve is the theoretical value of $(\partial K_T/\partial P)_T$. This figure is the basis for several conclusions about the mantle. First, the region between a depth of several hundred kilometers and about 900 km is not homogeneous. The variation of ϕ with depth in this region is much too rapid to be explained by compression of a uniform material, and the departure from expectation is so great that no reasonable adjustment of the parameters can bring agreement. We conclude that this region is characterized by change of composition, or change of phase, or both.

In the second place, the seismic values below about 900 km are everywhere close to the theoretical curve for an isothermal homogeneous layer. If there is a reasonably homogeneous layer anywhere in the mantle, it lies between 900 and 2900 km. Furthermore, if this region is homogeneous,

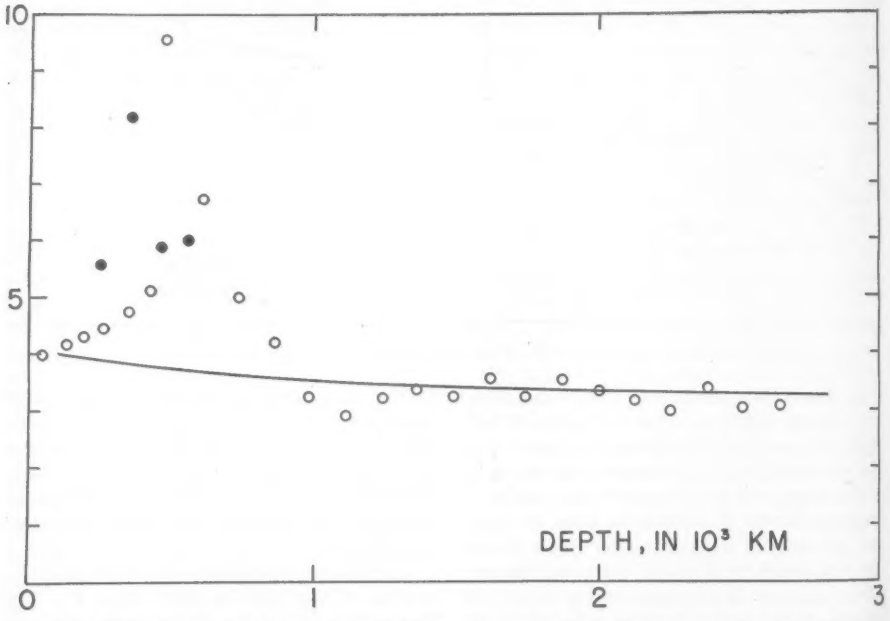


FIGURE 3. The function $1 - g^{-1}\,\Delta\phi\,/\,\Delta r$ *versus* depth in the mantle; open circles, after Jeffreys; solid circles, after Gutenberg. The theoretical value of $(\partial K_T/\partial P)_T$ is given by the smooth curve.

then be compared with the values of this variation obtained from the seismic velocities.

The seismic values of the quantity

$$1 - g^{-1}\,d\phi/dr$$

then the temperature terms must be limited to a few tenths of a unit, and consequently, the temperatures can scarcely exceed several thousand degrees, nor can the gradient exceed the adiabatic

gradient by more than a degree or so per km. As the adiabatic gradient itself is only a few tenths of a degree/km, the whole change of temperature in this layer, 2000 km deep, may not greatly exceed 1000°. We cannot regard the conclusions about temperature as more than very rough estimates because of the uncertainties of the various parameters, especially the principal one $(\partial K_T/\partial P)_T$, which might conceivably be several tenths of a unit higher than I have supposed. The conclusion with regard to homogeneity would not be seriously affected. Thus one of the necessary conditions for the application of the Adams-Williamson method appears to be satisfied for this region between about 900 km and the core. The other condition, that of adiabaticity, may be satisfied, but deviations that would be important for the density distribution cannot be definitely excluded by the present considerations.

If we accept the conclusion of homogeneity, we can find some of the properties of this layer, in particular the value of ϕ at zero pressure. A point-by-point computation leads us from the observed values to the zero-pressure values. These values are closely the same, since this is merely another and less sensitive test of homogeneity. What is important here is the absolute value of the ratio, close to 51 (km/sec)^2.

TABLE 1 shows the experimental values of the quantity ϕ for some materials of interest. These are all for ordinary temperature and pressure, and a correction must be applied before we attempt a direct comparison. The room temperature value for the material of the layer between 900 and 2900 km may be estimated as probably 60 (km/sec)^2 or more, *i.e.*, of the same order as the figure for corundum. The values for all of the silicates are too low, even the garnets falling below 45 (km/sec)^2. The olivines are far too low. There is no known material with a plausible composition which has also the required elasticity.

Our ideas concerning the chemical composition of the interior of the Earth are largely guided by stellar and meteoritic abundances, and we have reason to suppose that the major constituents of the minor planets are magnesium, oxygen, silicon, and iron. These elements have been thought to compose nearly the whole mantle, combined in such compounds as olivines and pyroxenes, which occur in the meteorites. These minerals, as we know them, cannot account for the elasticity of the deep mantle. A tighter, less compressible structure is required, and we conclude that a new phase or phases must exist in the layer between 900 and 2900 km. This is independent evidence in support of the conclusion already reached with respect to the layer between about 300 and 900 km, *i.e.*, that it is a transitional layer, in which composition or phase or both must change.

Bernal has supposed that at high pressures olivine might be transformed to a spinel structure, with higher density and elasticity. There is no serious basis for supposing that the whole interior has the composition of olivine; about half of the silicates of the stony meteorites are pyroxenes. Other possibilities are worth considering, such as a modification of enstatite, $(MgSi)O_3$, to a corundum, Al_2O_3, structure, or of silica, SiO_2, to a rutile, TiO_2, structure. Corundum and rutile possess elastic properties of the right order, so the idea

TABLE 1

PROPERTIES AT ONE ATMOSPHERE

Material	*Density*	ϕ_0 (km/sec)^2
Corundum	4	69
Beryl	2.8	67
Rutile	4.2	50
Periclase	3.6	47
Garnets	3.5–4.2	40–45
Jadeite	3.3	39
Forsterite	3.3	36
Anorthite	2.8	33
Fayalite	4.1	26
Iron	7.9	21
Albite	2.6	20
Quartz	2.7	14

that simple, close-packed, oxide structures of magnesium, silicon and iron may have the required properties, as well as a reasonable composition, does not seem far-fetched. All of these specific proposals are tentative, and merely suggest possibilities for further study. The requirement of new phases, however, seems to be unavoidable.

Ordinary olivine has been adopted by many writers as the principal component of the upper part of the mantle. Here the value of ϕ_0 is about 35 (km/sec)^2, a value close to that for forsterite (Mg_2SiO_4) at ordinary temperature. This leaves little margin for the effect of temperature or iron content, or for the tendency of the seismic velocities reported for this region to increase. There is an alternative solution, so far as elasticity is concerned, in an assemblage of garnets, pyroxenes, such as jadeite, and possibly olivines. This is a possibility long recognized as the "eclogite" hypothesis, eclogite being the name of a rock composed largely of garnets and a jadeite-like pyrox-

ene. The richer chemistry of the eclogite assemblage seems to offer a more promising basis for geochemistry and petrology.

A problem concerning the layer of transition is its great depth, some 500 or 600 km. It seems unlikely that a single phase change could be spread over so great a range of pressure, and a more plausible hypothesis is that a multicomponent system is involved, with a gradual change of the proportions of various phases, as well, very probably, of chemical composition. This layer may hold the key to a number of geophysical problems. The base of the layer of transition is close to the depth of the deepest earthquakes, about 700 km, and it is natural to look for an association of these shocks with the phase changes. If the formation of denser phases is still in progress, then the amount of surface contraction available for formation of mountains may be considerably greater than is usually estimated on the basis of simple thermal contraction alone. The theories of thermal convection are also affected; the principal region in which currents might operate, if at all, now seems to be limited to the deep layer between 900 km and the core.

The classical view that the core is mainly iron, as suggested by the occurrence of free metallic iron in the meteorites, has been challenged in recent years. On the one hand, Kuhn and Rittman have proposed that the Earth is nearly uniform throughout, consisting largely of hydrogen, or "solar material." On the other hand, Ramsey believes that the composition is uniform but that it is olivine; the core is supposed to be a metallic phase and the core boundary occurs at the pressure which determines the transition from nonconducting or semi-conducting silicate to metallic olivine. This idea arises by analogy with a similar transition which Wigner and Huntington proposed for hydrogen.

In my opinion, both of these theories fail to account for the high density of the core, the hydrogen theory by a factor of 10, and the olivine theory by a factor of 2. On the other hand, if we calculate the density of iron at the pressures of the core, we find values about 20 per cent too high for the liquid zone. This suggests the possibility of alloys formed with the abundant lighter elements, though a discrepancy of 20 per cent under these circumstances may be of little significance.

The inner core may be crystalline iron, the boundary being determined by the effect of pressure on the melting curve. The variation of velocity in the most recent study by Gutenberg, near the margin of the inner core, resembles the variation which takes place near the melting point of a solid. Furthermore, if we calculate the value of ϕ to be expected for solid iron in the inner core, and use this in conjunction with the observed velocity to find Poisson's ratio, we obtain 0.36, a reasonable value. The density of solid iron under these conditions would be between 14 and 15, which is also consistent with the requirements.

Ramsey believes that all of the inner planets should have identical chemical compositions, and, on the assumption that the mantle-core discontinuity in the Earth is a phase transition which occurs at 1.3 megabars, has calculated the mean densities of the other inner planets. This pressure is not reached in Mercury and Mars, so these planets should have relatively low densities. Unfortunately for this theory, the recent and probably most precise determination of the mass of Mercury by Rabe leads to a mean density of 5.3 ± 0.5, which requires a larger proportion of heavy material than in the Earth.

SECTION OF BIOLOGY

INTRAVENOUS LIPID EMULSIONS*

By E. D. GOLDSMITH†

The importance of the problem of being able to provide complete parenteral nutrition in the human requires no elaboration. In a paper published in 1935, Dr. L. Emmett Holt[1] reviewed the early experimental work pertaining to the introduction of fat emulsions intravenously. Special attention was directed to Yamakawa,[2] who was the first to develop a technique whereby large amounts of emulsified fat could safely be administered. Yamakawa and his collaborators, by homogenization, produced emulsions in which particle size was 2μ or less in diameter. Unaware of the work of the Japanese, Holt and his associates prepared fat emulsions which were administered by vein with beneficial therapeutic results. Further research, however, with parenterally-administered fat emulsions, reported in the years 1940–1950, could not be regarded as holding forth much hope for this method. A high mortality in the experimental dogs, and no apparent nitrogen-sparing action, contributed to this thought. Subsequent studies in the Harvard nutrition laboratories indicated that, under proper conditions, the animal survived treatment and that stabilized coconut oil emulsions cause a positive nitrogen balance in dogs. Extension of this work by two independent groups[3, 4] utilizing C14 indicated that the intravenously administered fat could be utilized and that this fat was readily available for utilization by the animal.

New difficulties have presented themselves, however. One is the high incidence of febrile responses reported by several groups of investigators. Whether this temperature rise is to be attributed to bacterial pyrogens or whether it is to be regarded as an inherent property of fat emulsions remains to be ascertained. The corroboration and explanation of these findings and the resolution of these difficulties becomes increasingly urgent and important since they are not in harmony with the clinical experience of other groups of investigators.

In view of the importance of the problem and its controversial aspects, it appeared desirable to discuss critically the various aspects of the intravenous lipid emulsion problem.

I hope this discussion will serve to resolve previously reported discrepancies and pin-point future areas of research in this very important field of nutrition.

* This paper was presented as part of the Symposium on Intravenous Lipid Emulsions at the meeting of the Section November 12, 1951.

† New York University College of Dentistry and Office of Naval Research.

References

1. HOLT, L. E., H. C. TIDWELL, & T. F. SCOTT. 1935. J. Pediat. **6:** 151.
2. YAMAKAWA. 1920. Nippon Naika Gakkai Zasshi **17:** 1, 22; YAMAKAWA & NOMURA. 1928. Jikken Iho. p. 523.
3. GEYER, R. P., J. CHIPMAN, & F. J. STARE. 1948. J. Biol. Chem. **176:** 1469.
4. LERNER, S. R., I. L. CHAIKOFF, C. ENTENMAN, & W. G. DAUBEN. 1949. Science **109:** 13.

CLINICAL STUDIES ON HEPATIC FUNCTION FOLLOWING ADMINISTRATION OF INTRAVENOUS FAT EMULSIONS*

By WILLIAM WADDELL, M.D., THEODORE B. VAN ITALLIE, M.D., ROBERT P. GEYER, Ph.D., AND FREDRICK J. STARE, M.D.†

The importance of fat as a source of concentrated calories in intravenous nutrition is beginning to receive wide recognition. Since 1942 this laboratory has been conducting researches on the preparation, stability, and physiologic uses of fat emulsions. In the last few years a fifteen per cent emulsion of vegetable oil, stabilizing material, dextrose, and water has been developed which has been given to several hundred patients. These emulsions provide 1600 calories per liter and, in many instances, administration of them has been associated with marked clinical improvement. Such emulsions are prepared by means of a dairy-type homogenization process. They contain 0.5 per cent purified soybean phosphatide and 1.0 per cent polyglycerol ester of oleic acid as emulsifying and stabilizing agents. The fat particles in the emulsions have a diameter of one micron or less and the emulsions themselves are stable to prolonged autoclaving. We feel it essential that an emulsion to be used in man must be one that is stable to autoclaving after it is bottled and sealed, for only by such means can one be reasonably sure of a sterile product. Even so, every batch of emulsion must be carefully tested for sterility.

Because of the increasing use of intravenous fat emulsions in man, it has become important to assess carefully the dangers potentially associated with repetitive administration of such preparations. Since the liver plays a central role in the metabolism of fat, attention has been directed to the effect on this organ of intravenous fat. In this paper we shall summarize this research.

The ability of the liver to remove from the blood stream and to metabolize intravenously-administered fat has been extensively studied in animals in our laboratory. It has been shown in dogs, for example, that bromsulfalein excretion is unaffected by the administration of large quantities of stable intravenous fat emulsion given for periods ranging up to six weeks. Direct analysis of livers from dogs receiving large quantities of intravenous fat has failed, moreover, to disclose undue accumulation of the fat. One positive finding in animals has been a transient drop in the cholesterol esters of the blood but this was found to occur also in animals which received only stabilizing material. Studies on choline-deficient and partially hepatectomized rats have shown that they retain their ability to mobilize intravenously administered fat in spite of the handicaps imposed upon them by these experimental lesions.

Analysis of liver function has been extended to human subjects receiving large quantities of intravenous fat. Twenty-five patients who received 5 to 45 liters of fat emulsion were studied. It should be considered that these were usually poorly-nourished, debilitated persons of advanced age. Most of them were suffering from severe surgical disorders and were subjected to one or more major operations during the same period that fat was being administered.

A standard liver "profile" was obtained for each subject prior to administration of the fat. This consisted of the following blood determinations: bromsulfalein excretion, cephalin flocculation, thymol turbidity, serum bilirubin, alkaline phosphatase, total serum protein and albumin-globulin partition, total cholesterol and cholesterol esters. These determinations were done at weekly intervals during and after administration of the fat. In general, no change that could be attributed to the fat was observed in any of the tests. In fact, in some instances liver function appeared to improve while patients were getting large quantities of intravenous lipid. A few of the patients showed transient bromsulfalein retention after a major abdominal operation. All of these individuals showed a return toward normal values despite continued administration of the fat, and it was believed that the operation was probably the cause of the dye retention. During the period of fat therapy, several subjects displayed a drop in cholesterol ester values. These returned to control levels when the administration of fat was discontinued.

In summary, preliminary studies relating to liver function were done on twenty-five patients receiving prolonged intravenous fat therapy. In spite of the fact that the persons receiving the fat were usually in extremely poor nutritional condition and in many instances underwent major surgery during the interval of fat administration, there was surprisingly little change in liver func-

* This paper, illustrated with lantern slides, was presented as part of the symposium on Intravenous Lipid Emulsions at the meeting of the Section of Biology on November 12, 1951.

† Department of Nutrition, Harvard School of Public Health; The Surgical Clinics, Massachusetts General and Peter Bent Brigham Hospitals.

tion as disclosed by the conventional liver function tests. A small number of patients receiving variable amounts of fat displayed a transient drop in the blood level of esterified cholesterol. As a result of the data obtained from these preliminary studies, it is concluded that intravenous fat emulsions of the type used and in the quantities given do not have a deleterious effect upon liver function.

THE ADMINISTRATION OF FAT EMULSIONS IN MAN*

By B. G. P. SHAFIROFF†

A variety of special studies have been involved in the development, production and clinical application of a fat emulsion suitable for parenteral alimentation in humans. To-date, a total of 750 subjects, all hospital patients, have received the fat emulsion intravenously or by clysis with hyaluronidase. The present observations have been based on actual clinical usage and the scope of study has varied from the effects of a single infusion to those effects obtained by multiple repeated infusions.

The development of a successful emulsion of fat is dependent upon complete and thorough homogenization and emulsification of the ingredients of the mixture. This has been accomplished by means of an industrial homogenizer specially modified for its present function. It is so designed that the working parts of the machine in contact with the fluids can be sterilized by autoclaving. The components of the emulsion, coconut oil, glucose solution and gelatin solution, all in sterile form and pyrogen-free, are poured into the homogenizer tank. A crude mix is formed there and automatically transferred to the pressure block in which the emulsification process is completed, at approximately 3,000 pounds pressure. The emulsion is continuously recyclized in this system for a 20-minute period and the finished product is collected in sterile flasks designed for intravenous infusion. The viscosity of the emulsion is that of a free flowing liquid, the pH is approximately 6.5, and the particle size is less than one micron. Protein hydrolysates or amino-acid solutions may be directly incorporated into the emulsion. The clinical investigations have been centered about the 10 per cent combined fat emulsion which, in addition to coconut oil, contained 5 per cent glucose and protein hydrolysate and was stabilized by about 2.4 per cent gelatin. The caloric value of one liter of this emulsion was 1,289 calories.

The purification and depyrogenization of coconut oil are important preliminary procedures prior to emulsification. This is accomplished by special filtration methods that remove foreign particles, spores and bacteria 0.2 of a micron or larger. In addition, the oil is washed with water and benzene to remove toxic polysaccharides. Finally the oil is autoclaved and emulsified with the other pyrogen-free ingredients. It is our belief that temperature elevations, noted in conjunction with the intravenous infusion of fat emulsions processed by such methods, cannot be explained on the basis of pyrogenicity.

The immediate reactions encountered after intravenous infusion of one liter of the fat emulsion have been classified. This data was obtained from patients in the post-absorptive state, who received the infusion during a four-hour period and were followed clinically for a period of 24 hours. No other food was permitted. Temperature elevations of less than 1.9 degrees were noted in 87 per cent. In the other 13 per cent, a temperature rise of two or more degrees above the pre-infusion temperature was found to develop. In four per cent of the latter group, the temperature elevation exceeded three degrees or more as a result of the fat infusion. In every case, the temperature rise was temporary and subsided quickly in less than 24 hours. The temperature reaction of the type just described has been regarded by us as thermogenic and distinguishable from the pyrogenic type. We believe that this thermogenic response can be correlated with the metabolic factors of fat oxidation. The nature of this reaction is still under study in our laboratory.

Symptomatic reactions to intravenous fat emulsions, classified according to frequency, were: headache, 2.5 per cent; chills, two per cent; vomiting, 1.5 per cent; nausea, one per cent; and dizziness, one per cent. As yet, we have not found any recipient sensitive to coconut oil. Skin tests preliminary to infusion of the emulsion have not proved of any diagnostic value. Of great interest is the observation that many subjects who reacted severely to the first infusion of fat emulsion subsequently received the emulsion with little or no reaction. In these cases, emulsions from the same batch of manufacture and even bottles containing a so-called "reactive" emulsion were re-infused. Toleration, or the acceptance adaptation for fat emulsions, remains to be interpreted further.

Laboratory tests of many kinds have been made for the determination of the immediate and late effects of single and repeated infusions of the fat emulsion. Hematologic follow-up studies

* This paper, illustrated with lantern slides, was presented as part of the Symposium on Intravenous Lipid Emulsions at the meeting of the Section of Biology, November 12, 1951.

† Department of Surgery, N. Y. U. College of Medicine, New York.

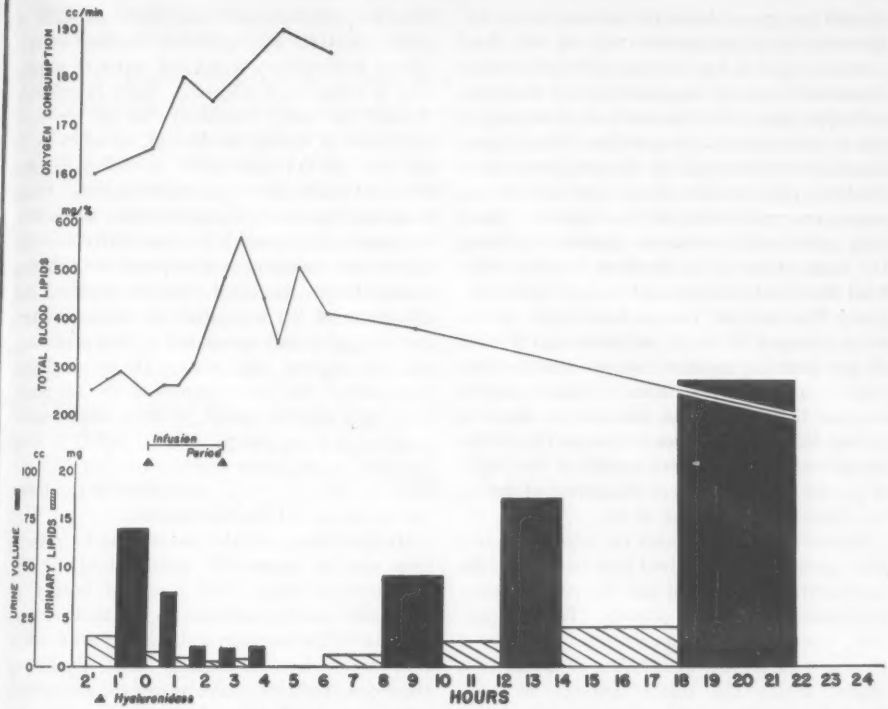


FIGURE 1. Graph of total lipids in blood and urine before, during and after the administration of 1 liter of the 10 per cent combined fat emulsion administered by clysis wth hyaluronidase. Note the increase in oxygen uptake during the rise in blood fat.

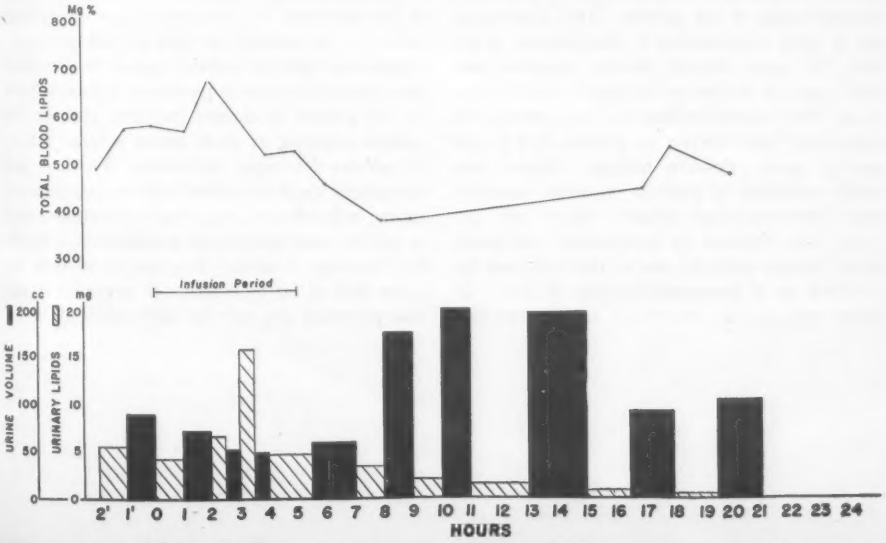


FIGURE 2. Graph of total lipids in blood and urine in association with the intravenous infusion of one liter of the 10 per cent combined fat emulsion. Note the similarity in the blood fat curves. The data for FIGURES 1 and 2 were obtained from the same patient.

showed no signs of hemolytic anemia due to fat. Quantitative micro-chemical tests of the blood showed a rapid increase in total lipids and a rather characteristic rate of disappearance from the blood, a disappearance which occurred on an average of two to four hours after completion of the infusion. Counts of chylomicrons in the peripheral blood reached a peak elevation and a rapid decline even before the termination of the infusion. Blood fatty acids tended to increase significantly during the acute phases of an emulsion infusion, while total blood cholesterol seemed to show little variation. The maximal loss of total lipids in the urine averaged 10 to 15 milligrams per liter of 10 per cent fat emulsion infused into patients with normal kidney function. A mild positive reaction for acetone was occasionally found in intermediate urine samples. This acetonuria was always temporary, occurred usually at the height of the fat infusion and was interpreted as due to the incomplete oxidation of fat.

Metabolic studies revealed the advantages of a high caloric potential derived from fat, both in the pre-operative preparation and the post-operative convalescence of surgical patients. In our experience, combinations of concentrated solutions of glucose with protein hydrolysate or amino-acids cannot attain the caloric potency of combined fat emulsions without threatening embarrassment of the cardio-vascular circulation, causing local thrombophlebitis, or requiring prolonged immobilization of the patient. The intravenous use of such combinations is complicated, moreover, by losses through urinary excretion and inefficiency of utilization of glucose and amino-acids. Fat in emulsion form has been found to be equal to, if not superior to, glucose as a protein sparing agent. Positive nitrogen balance was readily obtained in patients in severe inanition from gastro-intestinal disease. Many such patients were restored to near-normal nutritional status by the exclusive use of the combined fat emulsion as a therapeutic source of food. In acute experiments, deuterated fat incorporated into the emulsion provided direct evidence of early metabolic utilization by recovery of deuterium from urinary water and water of respiration of human test subjects. These experiments showed the ready availability of fat for rapid utilization in energy production, as much as 50 per cent of the deuterated fat being oxidized within 24 hours after intravenous injection. Other respiratory metabolic studies revealed an increase in oxygen uptake, which was correlative with the fat of the emulsion as the prime contributing energy factor, increased heat production, and alterations of the respiratory quotient. Numerous surgical biopsy specimens of liver and lung, specially stained with sudan IV or oil-Red-o, have proved the innocuousness of the fat emulsion from the standpoint of fatty degenerative reactions in these organs. Every variety of liver function test or kidney function test has similarly failed to show abnormal alterations in the latter due to the use of the fat emulsion.

Hyaluronidase and the emulsion in its present form can be successfully administered by the subcutaneous route. The ease and facility of absorption can be explained on the basis of particle size of the emulsion and the enzymatic effect of hyaluronidase. Laboratory tests similar to those described above have proved the absorption, diffusion and utilization of fat emulsions given by clysis for nutritive purposes.

The availability of methods for the preparation of fat emulsions for intravenous use opens new pathways for research in biology and medicine. Experiences with the present type of fat emulsion have proved its value in parenteral nutrition both for the patient in chronic inanition and for the patient requiring at short notice a large supply of calories for rapid utilization. Further, the therapeutic use of fat in the intravenous armamentarium will enhance other bodily functions, such as calcium and phosphorus mobilization, vitamin B effectivity, *et cetera*. It seems to us that the entire field of fat metabolism in normal and disease processes can now be fully explored.

THE LOCALIZATION OF PARTICULATE FAT IN INJURED BLOOD VESSELS*†

By W. B. McALLISTER AND L. L. WATERS‡

Since the work of Menkin it has been well known that the increased endothelial permeability that occurs in areas of inflammation favors the localization of intravascularly-injected dyes or other large molecular substances. In the experiments, advantage was taken of this principle to examine the localization of intravenously-injected emulsions of fat in the injured arterial wall. Emulsions prepared under the direction of Dr. Smith Freeman of Northwestern University were utilized. These emulsions, with particle sizes of approximately 1 micron or smaller contained ten per cent fat (olive oil), five per cent dextrose, and small quantities of asolectin, wetting agent and sodium cholate. In some of the emulsions, one per cent cholesterol or cholesterol ester was added. Injury of the coronary arteries of young dogs was obtained by intravenous injection of allylamine by a method previously described (Am. Heart J. 1948, **35**: 212). The animals were sacrificed at intervals up to one month following the above experimental procedures, and their blood vessels were studied.

Lipids in large quantities were found in the areas of acute injury in the coronary arteries. These apparently accumulated in the first weeks of injection and then were progressively removed from the artery wall. At the end of a month, in spite of continued injections, very little fat was left. Some phagocytosis of the deposited lipid occurred, but this was not a prominent feature of the fatty lesions.

* This paper, illustrated with lantern slides, was presented as part of the Symposium on Intravenous Lipid Emulsions at a meeting of the Section, November 12, 1951.

† Supported by the Life Insurance Medical Research Fund and the Office of Naval Research.

‡ Associate Professors of Pathology, Yale University School of Medicine, New Haven, Conn.

PROBLEMS IN THE PROVISION OF CALORIES PARENTERALLY*

By SIDNEY C. WERNER†

Considerable attention has been given in the past decade to the problems of parenteral nutrition. The needs of the body for total calories, electrolytes and protein nitrogen have been studied in the healthy, depleted and traumatized individual.[1] The present discussion concerns the need for, the agents available for, and some of the difficulties inherent in, the provision of calories parenterally.

The caloric and protein requirements of the healthy individual have been well-tabulated in terms of age, sex and activity requirements. Following trauma, however, a physiological change occurs, associated with loss of nitrogen from the body, often in the face of approximately the same intake of calories and protein. This phenomenon was termed "toxic destruction of protein" in the typhoid fever era[2, 3] and was noted at a later date to follow trauma, such as fracture, by Cuthbertson.[4] There has been no uniformity of opinion as to the mechanisms responsible for this loss of nitrogen. The extent of nitrogen loss tends to parallel the severity of the trauma. There is generally fever and lessened intake of protein and calories all the while tending to add a factor of undernutrition to the effect of the injury in promoting nitrogen loss. The factors of variable diet and protein intake have been carefully controlled in a series of patients undergoing hernia repair and cholecystectomy.[5] Little, if any, increase in the loss of nitrogen resulted after operation when the usual postoperative nutritional program was given before the procedure as well as after. If an adequate calorie and protein intake was maintained unchanged through the period of operation, nitrogen equilibrium could be sustained in most instances. The effect of trauma in the absence of infection thus appears to be not much greater, if at all, than the effect of undernutrition.

The extent of loss of nitrogen following the average surgical procedure is generally not sufficient to cause physiological repercussions. In the previously depleted patient, in the patient with a serious infection or injury, or in the presence of a prolonged complication, the problem of nutrition becomes urgent. When the oral route is not available because of inability to ingest food, diarrhea, *et cetera*, parenteral administration must be used.

To date, glucose and amino acid or protein hydrolysate solutions are given for this purpose, with electrolytes when necessary. A five per cent glucose solution contains 50 gms. of glucose per liter and provides 200 calories. A ten per cent solution is hypertonic and is apt to cause venous thrombosis. Amino acid and hydrolysate preparations include water of crystallization and offer about 280 to 340 calories per liter of ten per cent solution. It is thus immediately seen that the provision of an adequate caloric and nitrogen intake by these means requires the introduction of large volumes of fluid parenterally. The usual tolerance for intravenous fluids is three to four liters per day and may be less in older people, where the factors of loss of cardiac reserve and renal difficulties may be present.

Fructose has been introduced as a source of calories.[6] It has been shown that fructose is handled by the liver and kidney differently than glucose, so that urinary spillage may be lessened. Since fructose has the same osmotic pressure as dextrose, however, solutions containing five per cent dextrose and five per cent fructose are hypertonic, just as with ten per cent dextrose. Significant loss of fructose by the kidney, moreover, has been found in the very brief experience of this clinic. The caloric value of fructose is four calories per gram.

Alcohol too has been employed for its caloric value.[7] One gram provides seven calories but one c.c. by volume offers only 5.6 calories. The use of alcohol is limited by its action as a central nervous system depressant. In this clinic, slow rate of administration, occasional euphoria and "hangover" reactions have prevented its being used on any but research problems. The evidence is not clear, moreover, that the calories provided by alcohol are physiologically and efficiently utilizable.

Fat emulsion remains the most hopeful future source of calories. In this clinic, an emulsion patterned after the emulsion of Stare and coworkers[8] has been used recently. Previous experience with emulsions containing gelatin has not been entirely satisfactory due to difficulties in preparation and persistence of high concentrations of gelatine in blood and urine after the infusion of the emulsions.

* This paper, illustrated with lantern slides, was presented as part of the Symposium on Intravenous Lipid Emulsions at a meeting of the Section of Biology, November 12, 1951.

† Department of Medicine, College of Physicians and Surgeons, Columbia University, and the Presbyterian Hospital in the City of New York

Two types of untoward reactions have been met with emulsions stabilized with lecithin. The first has been an immediate reaction with precordial and lower chest pressure and pain. A similar reaction is known to follow the rapid introduction into the blood stream of colloid solutions with relatively large particle size. The second is a delayed rise in temperature, usually in the second hour of the infusion. One or both of these reactions with lecithin-stabilized preparations have been encountered in over a third of our subjects. In view of this high incidence, it is felt that the physiological effects of such emulsions may be obscured by a "stress" response on the part of the recipient.

Derivatives of fat have recently been suggested. Kinsell and his group are studying octanoic acid. LeVeen[9] has suggested the study of dicarboxylic fatty acids. The difficulty with smaller chain fatty acids is the loss of caloric value per gram compared to the oils currently in use. The ability of the body to use dicarboxylic fatty acids, and their toxicity, is unknown.

Summary. (1.) The agents available for the provision of calories parenterally have been briefly reviewed. (2.) The main problems consist of total fluid volumes required, osmotic pressure of the solutions used, rate of administration, renal loss of administered material, toxic reactions, and physiological response of the recipient.

References

1. Werner, S. C. 1948. Problems of parenteral nutrition. Am. J. Med. **5:** 749.
2. Coleman, W. & E. F. Dubois. 1915. Clinical calorimetry. VII. Calorimetric observations on the metabolism of typhoid patients with and without food. Arch. Int. Med. **15:** 887.
3. Krehl, L. 1905. The Principles of Clinical Pathology. (Translation by Hewlett.) Lippincott Co. Philadelphia, Pa.
4. Cuthbertson, D. P. 1932. Observations on the disturbance of metabolism produced by injury to the limbs. Quart. J. Med. **1:** 233.
5. Werner, S. C., D. V. Habif, H. T. Randall, & J. S. Lockwood. 1949. Post-operative nitrogen loss: A comparison of the effects of trauma and of caloric readjustment. Ann. Surg. **130:** 688.
6. Carpenter, T. M., & R. C. Lee. 1937. The effect of fructose on the metabolism of ethyl alcohol in man. J. Pharm. & Exper. Ther. **60:** 286.
7. Rice, C. O., O. Stricker, *et al.* 1948. Parenteral nutrition. Pre- and post-operative use of glucose, amino acids and alcohol. Lancet. **68:** 91.
8. Shoshkes, M., T. B. Van Itallie, R. P. Geyer, & F. J. Stare. 1951. Fat emulsions for oral nutrition. III. Use of orally administered fat emulsions as caloric supplements in man. J. Amer. Dietetic Assn. **27:** 197.
9. LeVeen, H. H., G. Papps, & M. Restuccia. 1950. Problems in the intravenous administration of synthetic and natural fats for nutritional purposes. Am. J. Digestive Dis. **17:** 20.

SECTION OF MATHEMATICS AND ENGINEERING*

AERO-THERMODYNAMIC PHENOMENA IN A REVOLVING FLUID MOTION†

By PAUL H. SAVET‡

Introduction. The investigation which follows has been inspired by a development work carried out by the writer relative to the operation (from an aerodynamic and thermodynamic viewpoint) of a device known as the Ranque tube, Hilsch tube or Vortex tube.

This device essentially consists of a small, elongated cylindrical hollow tube (T) in FIGURE 1 into which air at high pressure is supplied through an entrance nozzle (N). The latter is located tangentially to the inner circular wall of the tube, close to the axial end (C). Within the enclosed cavity of the tube a whirling motion is communicated to the air, while the latter expands to the pressures prevailing at the discharge ends H and C. The flow of the air in the tube is made to split into two separate streams, and discharged respectively through central openings C and H. Experience shows that the airstream discharged at C is much colder than the entrance air, while at the opposite end of the tube (H) the discharged air is much hotter.

This quite interesting phenomenon has been known for more than twenty years[1] through the writings of G. J. Ranque, who in 1932 forwarded the first attempt of a theoretical explanation of its operation. The device constructed by Ranque remained almost unknown, however, until World War II, when the potentiality of the latter as an aircooling apparatus has been recognized and its application envisioned in airplane cabin cooling, or possibly other uses, in which considerations of light weight and utmost simplicity are paramount.

The investigations carried out more than ten years after Ranque's pioneering work by R. Hilsch[2] aroused a universal interest. Many experimental and theoretical analyses followed Hilsch's meritorious effort, while today the field is quite crowded, if judged by the number of individual scientists or industrial laboratories engaged in perfecting this device—or attempting to do so.

This overcrowding is not due to a scientific interest alone. Indeed, the original Ranque tube, attractive as it may be, is desperately inefficient, thermodynamically speaking, as compared to an aircycle expansion turbine operating at the same overall pressure ratio of expansion. Yet, in spite of sustained efforts, neither the aforementioned inventors of the device nor subsequent scientists ever published an adequate explanation of the operation of this challenging device. There is not even an analysis of the efficiency available on an intrinsic, *i.e.*, "figure of merit" basis, showing whether an improvement of the device, as governed by the law of diminishing returns is achievable at all.

It is felt that a correct analysis of the device would be very desirable in order to assess the precise potentialities left open for further improvements; or to show, if this is the case, that the maximum performance of the tube has already been attained with no margin of improvement still left open.

Preliminary Considerations. Any aircycle cooling system (aside from a heat exchanger) operates on this overall apparent principle: Work is extracted from the air through expansion within a field of falling pressure, while the entrance and exit velocities are equal or comparable. Thus, in an expansion turbine the nozzle alone does not change the internal energy and, therefore, the total temperature of the air, because the static pressure drop is offset by the resulting acceleration. Nevertheless the combination of nozzles and wheel of a complete stage precisely accomplishes this extraction of work; it yields comparable exit and entrance velocities while the static pressure within the stage has fallen.

While a conventional turbine stage exhibits a pressure drop, and as a rule no acceleration of the air, the cooling end of the vortex tube goes further: it combines a pressure drop with a negative acceleration. As to the hot end of the tube, it is also a freak: it provides, by recovery of the prevailing kinetic energy, a boost of the initially existing static temperature which is already as high as the total temperature of the air ahead of the entrance nozzle.

Considered thus as a whole, with no extraction of internal energy, the vortex tube operates on the basis of a constant mean total temperature, pro-

* A paper, entitled "Superconductivity," by Mark W. Zemansky, College of the City of New York, was presented at a meeting of the Section of Physics and Chemistry on November 13, 1951, but the abstract had not been received prior to publication of this issue of TRANSACTIONS.

† This paper, illustrated with lantern slides, was presented at the meeting of the Section on November 16, 1951.

‡ Research Laboratory, Arma Corporation, Brooklyn, N. Y.

vided that the weighted average of both, hot and cold, ends are simultaneously considered. Due to the particular aerodynamic conditions, a split around the mean total supply temperature (T_1) occurs, as imposed by an aerodynamic forcing function, naturally absent in an ordinary revolving, *i.e.*, free vortex, motion.

Analysis of a Two Dimensional Flow with External Forcing. As customary in thermodynamics, we shall call static temperature (T) the one supposedly measured by a thermometer entrained by the flow; while the total temperature (T_{tot}) exceeds T by a corrective term proportional to the velocity squared. Thus:

$$\begin{cases} T_{tot} = T + \dfrac{V^2}{2K} \\ K = Jc_p g \end{cases} \tag{1}$$

The total temperature is registered by a thermometer at rest placed within the flow.

The cylindrical equations of inviscid fluid dynamics yield the prime integral

$$T - T_0 = \frac{1}{K}\int_0^r \left(\frac{v^2}{r} - v_r\frac{\partial v_r}{\partial r}\right) dr = \frac{1}{K}\int_0^r \frac{1}{\rho}\frac{\partial p}{\partial r}\, dr \tag{2}$$

with the local relationship of temperatures as in equation 1, where $V^2 = v_r^2 + v^2$. It follows that:

$$T_{tot} - (T_{tot})_0 = \frac{v^2 - v_0^2}{2K} + \frac{1}{K}\int_0^r \frac{v^2}{r}\, dr. \tag{3}$$

Let us consider a group of plane revolving flows represented by the formula:

$$v = v_1\sigma^{n/2} \tag{4}$$

with $\sigma = (\frac{r}{R})^2$ to which, among others, the free vortex flow ($n = -1$) and the solid wheel type motion ($n = 1$) belong.

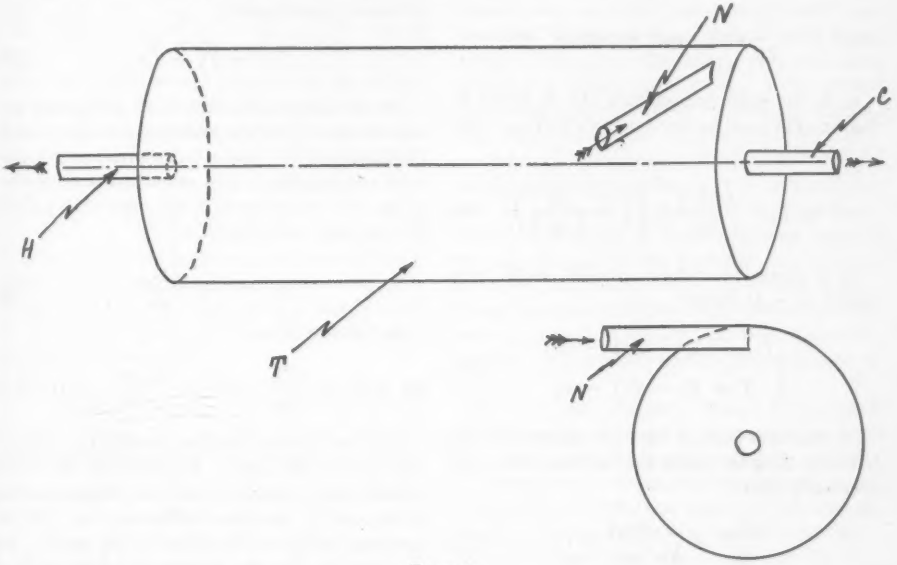


FIGURE 1

The constant average total temperature (weighted linearly with respect to σ) should be equal to T_1. Thus:

$$T_1 \equiv \int_0^1 T_{tot}(\sigma)k(\sigma)\, d\sigma = k'\int_0^1 T_{tot}(\sigma)\, d\sigma. \tag{5}$$

Supposing $n \neq -1$, equation (3) yields:

$$T_{tot} - (T_{tot})_0 = \frac{n+1}{n}\frac{v^2 - v_0^2}{2K} = \frac{n+1}{n}\frac{v_1^2}{2K}(\sigma - \sigma_0) \tag{6}$$

and therefore:

$$\frac{T_1}{k'} = (T_{tot})_0 + \frac{n+1}{n}\frac{v_1^2}{2K}\left(\frac{1}{2} - \sigma_0\right). \quad (7)$$

Elimination of the temperature at $\sigma = 0$, *i.e.*, $(T_{tot})_0$ provides the total temperature:

$$\begin{cases} T_{tot} = \dfrac{T_1}{k'} - \dfrac{n+1}{2n}\dfrac{v_1^2}{2K}(1 - 2\sigma) \\ \qquad \approx T_1 - \dfrac{n+1}{2n}L(1 - 2\sigma) \end{cases} \quad (8)$$

where $L = \dfrac{v_1^2}{2K}$ and, closely enough, $k' \approx 1$.

As to the static temperature (T), it should be theoretically equal for any value of σ to $T_{tot} - L\sigma$. Or explicitly:

$$T \approx T_1 - \frac{n+1}{2n}L\left(1 - \frac{2\sigma}{n+1}\right). \quad (9)$$

As a particular instance, a solid wheel type motion ($n = 1$) yields:

$$\begin{cases} T_{tot} = T_1 - L(1 - 2\sigma) \\ T = T_1 - L(1 - \sigma). \end{cases} \quad (10)$$

On the other hand, if the total temperature distribution along the radius were uniform, one would necessarily have:

$$\frac{dT_{tot}}{dr} \equiv \frac{v}{Kr}\frac{d(rv)}{dr} = 0 \quad (11)$$

i.e., a free vortex flow ($n = -1$).

Finally, for whatever value of n, one has:

$$\frac{\partial}{\partial T_1}\left(\frac{dT_{tot}}{dr}\right) \equiv 0. \quad (12)$$

The radial total temperature differences (everything else being the same) are independent of the entrance temperature (T_1).

If a circular flow, of whatever initial distribution of velocities (v) along the radius, is left free to evolve toward a condition of equilibrium, it will tend to assume a velocity distribution $v(r)$ which corresponds to the highest entropy, *i.e.*, a uniform distribution of total temperatures. Eliminating the static temperature gradient $\frac{dT}{dr}$ from the basic equations:

$$\begin{cases} \dfrac{dT}{dr} = \dfrac{v^2}{Kr} \\ \dfrac{dT_{tot}}{dr} = \dfrac{dT}{dr} + \dfrac{v\,dv}{K\,dr} \end{cases} \quad (13)$$

one gets

$$K\frac{dT_{tot}}{dr} = \frac{v}{r}\frac{d(rv)}{dr}. \quad (14)$$

A uniform total temperature distribution corresponds to a free vortex motion $v = c/r$. The static temperature, as per equation 9 for $n = -1$, becomes (theoretically):

$$T = T_1 - L\sigma \quad (15)$$

On the other hand, if it is as customarily assumed, that a particle undergoing a small radial displacement (dr) momentarily preserves its own total temperature, is thus submitted to the action of its new environment; it will experience a force δF (per unit mass) equal to:

$$\delta F = -K\frac{dT_{tot}}{dr}. \quad (16)$$

Stability requires:

$$\delta F < 0 \text{ or } \frac{dT_{tot}}{dr} > 0 \text{ or } \frac{d\,|rv|}{dr} > 0 \quad (17)$$

a result well known since the investigations carried out by Lord Rayleigh.[3] In particular, the "solid wheel" type of motion within the device is stable; as imposed by the rim conditions at $\sigma = 1$ by the entrance motion in the plane of the nozzle. Its maintenance does not require any other supply of energy than the one spent in the transient condition from a free vortex motion to the solid wheel type of flow.

In planes of revolution farther away from the nozzle toward H, the total temperature differential along the radius becomes attenuated, until the other end (H) of the tube is reached, where T_{tot} is supposedly uniformly distributed along the radius. If z denotes the axial distance from the plane of the nozzle toward the hot end of the tube, the device behaves as if one were to assume that L, as occurs in equation 10, decreases from its theoretical maximum of $\frac{v_1^2}{2K}$ (for $z = 0$) to zero (for $z = \max$).

Another point in the overall analysis of the device is the actual pressure ratio which enters

directly in the production of maximum theoretical total temperature differential prevailing within the device.

The supply temperature of the air ahead of the nozzle is T_1. But so is the static temperature within the tube, past the nozzle (for $\sigma = 1$) in the conditions of equilibrium as shown by equation 10. Using notations as listed, one has:

$$\bar{\omega} = \bar{\omega}_n \times \bar{\omega}_t \quad \text{or}$$
$$1 + y = (1 + y_n)\,(1 + y_t). \tag{18}$$

It also appears that:

$$L = \frac{v_1^2}{2K} = T_1 \frac{y_n}{1 + y_n} = T_1 \frac{y_t}{1 + y_t} \tag{18-a}$$

since the kinetic energy produced in the nozzle, expressed as a static temperature differential L, is equal to the maximum static temperature differential prevailing in the tube. This shows that one necessarily has $y_n = y_t$ and thus

$$\bar{\omega}_n = \bar{\omega}_t = \sqrt{\bar{\omega}}. \tag{19}$$

In other words, the pressure ratio actually entering in the production of total temperature differentials (L) on either side of T_1 is merely equal to the square root of the overall pressure ratio available for expansion.

This is an essential penalization sustained by the vortex tube, if compared to the operation of a turbine. Indeed, for a given overall pressure ratio ($\bar{\omega}$) the theoretical static temperature drop for a turbine is $T_1 \frac{y}{1 + y}$ as against a possible extreme of $T_1 \left(1 - \frac{1}{\sqrt{1 + y}}\right)$ in the vortex tube. The ratio

$$f = \frac{1 - \frac{1}{\sqrt{1 + y}}}{\frac{y}{1 + y}}$$

is of the order of $\frac{1}{2}$ for $y = 0$, while for very large values of y, f is equal to 1. For $\bar{\omega} = 6$ for instance, $y = .659$ and thus $f = .563$. This is a severe handicap of the tube, which should make any direct comparison with an expansion turbine unfair. There are other factors which contribute to the unfavorable relative position of the Ranque tube. We shall see them shortly.

The expansion of the air within the nozzle is accompanied by an acceleration up to the entrance velocity v_1. Denoting the static temperature drop resulting from said acceleration by $L = \frac{v_1^2}{2K}$ and remembering that the total temperature within the nozzle stays unaltered, it would seem that the total temperature, as measured in the actual sustained revolving flow at $\sigma = 1$ near the nozzle, should also be equal to T_1. Equation 10 shows, however, that this is not true: for $\sigma = 1$, T_{tot} is theoretically (and closely) equal to $T_1 + L$. It should be remembered that any reasoning of total vs. static temperatures in a flow (as a function of the acquired kinetic energy) can be expressed only as a mean variation of static temperatures, related to mean variations of kinetic energies. In a one dimensional flow the above remark is of no particular interest. In the present investigation, however, the temperature distribution should follow both the first principle of thermodynamics, as expressed by equation 5 and the radial equilibrium conditions of a sustained motion as expressed by equation 10. The simultaneous observance of these equations explains not only the split of the airstream into cold and hot layers, but also eliminates the somewhat paradoxical appearance of a seemingly stationary static temperature within the entrance nozzle; notwithstanding the important acceleration undergone by the air.

Mass Efficiency, Figures of Merit. If the overall kinetic energy, expressed on a temperature scale by L at the entrance nozzle, were fully available for splitting the airstream into hot and cold layers, we would have a total and static temperature distribution as a function of σ as shown by FIGURE 2. The total temperature would vary from $T_1 - L$ to $T_1 + L$. The static temperature variation would meanwhile also be linear, and amounting to half as much.

If the "cold" air collected through C is supposed mainly to affect the layers comprised between 0 and σ, its estimated temperature would be in first approximation $T_c = T_1 - (1 - \nu)\,L$, while the "hot" temperature is $T_1 + \nu L$.

In these expressions, ν represents the mass efficiency of the tube, defined as the ratio of the mass of cold air collected against the total amount of air supplied at the entrance.

We have also seen that not all the planes of revolution perpendicular to and along the axis of the tube exhibit the same value of L. If the apparent value of the kinetic energy entering in the production of temperature spread in the tube

be denoted by L times a coefficient (this coefficient being η_c and η_h for the cold and hot flows respectively), one would have cold and hot temperatures as follows:

$$\begin{cases} T_c = T_1 - \eta_c (1 - \nu) L \\ T_h = T_1 + \eta_h \nu L. \end{cases} \tag{20}$$

On the other hand, the first principle of thermodynamics, written as a continuity equation, requires:

$$\nu T_c + (1 - \nu) T_h \equiv T_1 \tag{21}$$

which, explicitly developed, yields

$$\eta_c = \eta_h = \eta. \tag{22}$$

In other words, the "heating efficiency" is equal to the "cooling efficiency." It represents the efficiency (η) of the tube, a figure of merit, inasmuch as it measures the degree of perfection attained by the device. The upper limit of η is equal to one, and therefore has an intrinsic significance.

Let us take a few performance figures obtained by R. Hilsch and discover the figures of merit involved. The tube investigated is described as tube No. 2 in Hilsch's referenced article. Temperatures are in centigrade degrees. $T_1 = 293°K$ and $\nu = .20$. L has been calculated by the formula:

$$L = T_1 \left(1 - \frac{1}{\sqrt{1 + y}} \right) \tag{23}$$

and ηL by using experimental data and the formula

$$\eta L = \frac{T_1 - T_c}{1 - \nu} \tag{24}$$

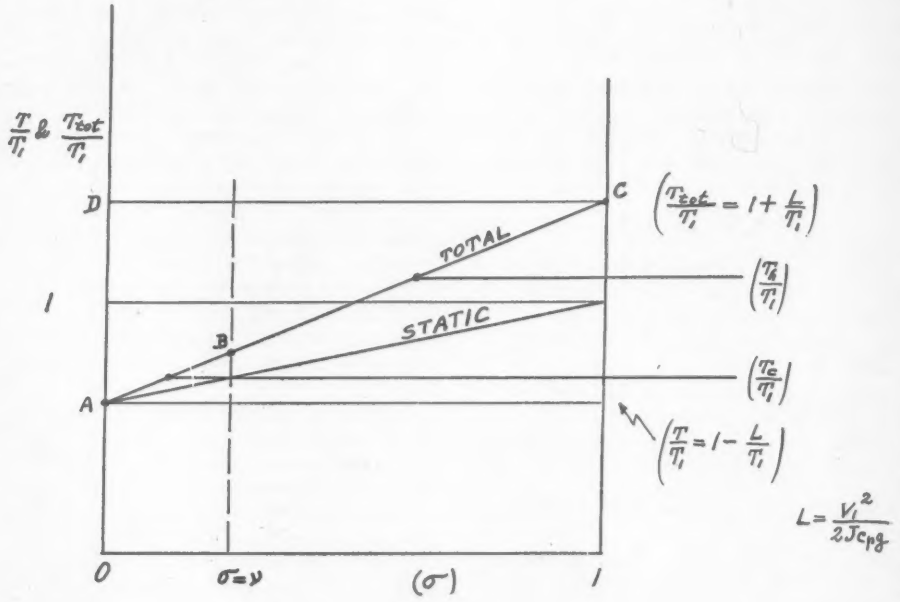


FIGURE 2

Pressure ratios up to 11/1 have been considered.

$\bar{\omega}$	L	ηL	η
1	0	0	—
3	43	27	.79
5	59	39	.83
7	71	48	.85
9	79	55	.87
11	85	62	.91

It is readily seen that, contrary to R. Hilsch's belief, apparently shared by everybody, the efficiency of the vortex tube, if measured on an intrinsic (figure of merit) basis, is excellent! This does not mean, of course, that the device compares favorably with the turbine; but on account of the law of diminishing returns, it is hopeless to attempt to improve it—as such—no matter how discouraging its performance may appear with respect to a device utilizing the full pressure ratio of expansion and the full amount of the airsupply involved.

Indeed, compared to the turbine, the figures of utilization are poor, although the best of potentialities has been extracted from the tube.

If the temperature of the compartment to be refrigerated be denoted by τ, the cooling ability of an expansion turbine per lb of air handled is:

$$G_{\text{turbine}} = c_p\left(\tau - T_1 + T_1\eta'\frac{y}{1+y}\right) \quad (25)$$

negative BTU/lb

(η' being the adiabatic efficiency of the turbine), while the tube barely yields a number of negative BTU/lb equal to:

$$G_{\text{tube}} = \nu c_p\left[\tau - T_1 + (1-\nu)T_1\,\eta\left(1 - \frac{1}{\sqrt{1+y}}\right)\right]$$

negative BTU/lb (25–a)

Let us take, for the sake of simplicity, the instance of $\tau = T_1$; thus considering only the number of negative BTU/lb produced with respect to the entrance temperature T_1. Let us assume $\eta = .90$ and $\eta' = .70$. Furthermore, suppose $T_1 = 660°\text{R}$ (200°F). We have:

$$\left\{\begin{aligned} -G_{\text{turbine}} &= .243 \times 660 \times .70\,\frac{y}{1+y} \\ &= 112\,\frac{y}{1+y} \\ -G_{\text{tube}} &= \nu(1-\nu) \times .243 \times .90 \times 660 \\ &\qquad \left(1 - \frac{1}{\sqrt{1+y}}\right) \\ &= 144\nu\,(1-\nu) \\ &\qquad \left(1 - \frac{1}{\sqrt{1+y}}\right) \end{aligned}\right. \quad (26)$$

$|G_{\text{tube}}|$ is maximum for a mass efficiency (ν) equal to:

$$\text{optimum } \nu = \frac{1}{2}\left(1 - \frac{1}{\eta}\,\frac{1 - \frac{\tau}{T_1}}{1 - \frac{1}{\sqrt{1+y}}}\right) \quad (27)$$

In case of $\tau = T_1$, *i.e.*, optimum value of ν equal to $\frac{1}{2}$, we have the following table:

$\bar{\omega}$	G_{tube}	G_{turbine}	$G_{\text{tube}}/G_{\text{turbine}}$
1	—	—	—
3	5.22	30.0	.174
5	7.29	41.0	.182
7	8.70	47.4	.185
9	9.67	51.8	.187

while, for $\tau < T_1$, optimum ν is $\ll \frac{1}{2}$, as shown by the table for $\tau = 80°\text{F}$ (540°R)

$\bar{\omega}$	optimum ν
1	—
3	—
5	0
7	.082
9	.125

It appears that there is a further penalization of the tube in the instance just tabulated. For an overall pressure ratio of 9/1 for instance $\nu = \frac{1}{2}$ yields $|G_{\text{tube}}| = 9.67$ BTU/lb; the mass efficiency of $\nu = .125$, which corresponds to $\tau = 80°\text{F}$, yields $|G_{\text{tube}}| = 4.22$ BTU/lb. The performance of the tube under these conditions would be only $\frac{4.22}{51.8} = .0815$ times the performance of an expansion turbine operating under identical conditions of extreme pressures and entrance temperature! Also, for lower pressure ratios ($\bar{\omega}$) even a low mass efficiency (ν) would not yield an exhaust temperature (T_e) lower than τ, as required for purposes of refrigeration.

For an efficiency of $\eta = .90$, the temperatures to be obtained in a Ranque tube at the cold end are represented in FIGURE 3, together with the theoretical maximum prevailing within the tube. As

pointed out before, the radial distribution of total temperatures in diff rent planes of revolution, other than the one containing the nozzle, shows torted with respect to their shape shown, as a result of the flow through either axial end of the tube; as such, they provide however a good

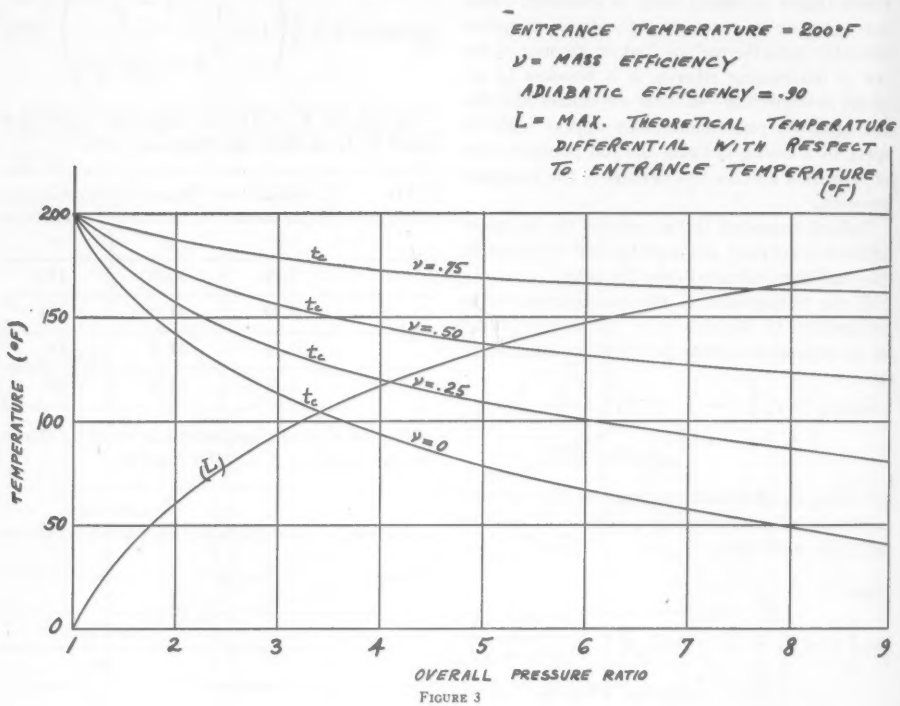


FIGURE 3

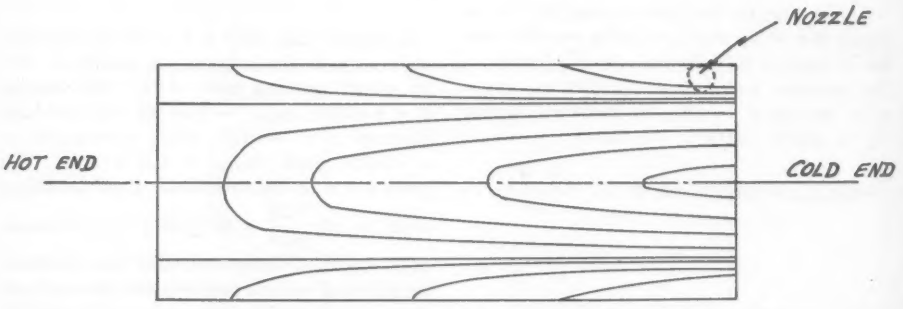


FIGURE 4

smaller extremes as the distance from the nozzle increases.

A theoretical investigation conducted by the writer shows total isothermal lines in a tube as represented in FIGURE 4. The curves get distorted with respect to their shape shown, as a result of the flow through either axial end of the tube; as such, they provide however a good overall picture of the distribution of total temperatures, if extraneous thermal disturbances, conductivity through walls, etc. are disregarded.

FIGURE 4 shows, among other things, that the collection of hot air at the "hot end" of the tube

does not mean that the hottest point should necessarily be in the "hot" region, provided necessary precautions are taken.

C reful analysis of these facts enabled the writer to circumvent the barrier raised by the already high intrinsic efficiency (η) of the tube. Obviously the value of η cannot be made higher than it presently is. But other thermodynamic cycles, utilizing actual total temperature distributions, open new avenues for improvement, without having to face the impossible task of raising η.

Already, important progress has been made in this direction, and it is felt that the above mentioned field has hardly been explored yet to any appreciable extent.

Nomenclature

$( )_0$	at r = 0.
$( )_1$	at r = R.
$( )_n$	relative to nozzle.
$( )_t$	relative to tube.
$( )_c$	relative to cold end.
$( )_h$	relative to hot end.
T	static temperature (°R).
T_{tot}	total temperature (°R).
T_1	supply temperature (°R).
$\bar{\omega}$	overall pressure ratio.
γ	ratio of specific heats of air $\approx$ 1.395.
y	$\bar{\omega}^{(\gamma-1)/\gamma} - 1 = \bar{\omega}^{.283} - 1$.
J	mechanical equivalent of heat = 778 ft × lb/BTU.
g	acceleration of gravity = 32.2 ft/(sec)^2.
c_p	specific heat of the air at constant pressure $\approx$ .243 BTU/lb.
K	Jc_pg = 6080 (ft/sec)^2/°F.
V	absolute velocity ft/sec ($V^2 = v_r^2 + v^2$).
v	tangential velocity ft/sec.
v_r	radial velocity ft/sec.
r	current radius ft.
R	maximum inner radius in the tube ft.
σ	$\left(\frac{r}{R}\right)^2$.
L	$\frac{v_1^2}{2K}$ (°F).
ν	mass efficiency.
η	intrinsic efficiency or figure of merit of the tube.
η'	adiabatic efficiency of turbine.
τ	absolute temperature of the compartment to be cooled (°R).
G	cooling ability of tube or turbine BTU/lb of air consumed.

References

1. Ranque, G. J. 1933. Bulletin de la Société Française de Physique. série **7:** 112.
2. Hilsch, R. 1947. Review of Scientific Instruments. **18:** 108.
3. Rayleigh. 1916. Proceedings of the Royal Society, series A. **93:** 148.
4. Kassner, R., & E. Knoernschild. 1947–1948. Technical Report F-TR-2198-ND. USAF.
5. Knoernschild, E., & O. Morgensen. 1948. Technical Report MCREXE-664-510 A. USAF.
6. Corr, J. E. 1948. Vortex tube data folder. GE Research Laboratory.
7. Reed, G. E. 1947. MIT Master Thesis.
8. Fulton, C. D. 1950. Journal of the ASRE. 473.
9. Vonnegut, B. 1950. Review of Scientific Instruments. **21:** 136.

READING AND VISUAL WORK: A CONTRIBUTION TO THE TECHNIQUE OF EXPERIMENTATION ON HUMAN FATIGUE*

By LEONARD CARMICHAEL†

In recent years a number of experiments on fatigue have been conducted in the laboratory of sensory psychology and physiology at Tufts College.[1] In some of these experiments groups of subjects have been deprived of normal sleep and kept active for periods in excess of three days. In certain phases of these studies, long enforced walks and other taxing activities have been required during the experimental periods. Under these conditions it has been found in general that, in spite of subjective feelings of fatigue, social quarrelsomeness, and personality modification, all subjects seem able to "pull themselves together" so as to do well on very specific brief tests given at any time during long fatiguing periods.

Tests have been used involving the crossing out of special letters in Spanish printed solid, doing stereoscopic range findings, eye-hand tracking, differential brightness discrimination, and complex visual reaction time. In all such tests, the subjects for the most part did as effective work in brief samples of activity at the end of seventy-four hours, for example, as when fresh and well rested.

This conclusion bears on the present paper which is intended to evaluate certain aspects of an elaborate study on reading and visual fatigue conducted in this same laboratory at Tufts College and also reported elsewhere.[2]

In the present paper an effort is made to show that in experiments on reading to which reference is made, certain controls were used which are not customarily available in studies of human fatigue. The fact to be emphasized is that in these experiments all of the eye movements made during each reading period of six hours were electrically recorded. Forty subjects read for two such periods. A total estimated to be in excess of five miles of records were therefore available for study at the conclusion of the experiment. This continuous-record technique provides a new approach to the study of work and of the possible work decrement produced by long continued reading. In this respect it was quite distinct from the other studies mentioned in the first paragraph above. In these general studies long periods of fatiguing activity were interrupted at stated times by short, required test periods. These performances were taken as constituting measures of the subject's state of fatigue or its lack.

It is increasingly clear, on the basis of much work, that the human organism is so constituted that its energies can be mobilized effectively for short periods even when there may be present a general decrement of the capacity of the organism for long continued and monotonous work. Factors related to attention and to the blocking of responses apparently can be compensated for by subjects who are asked merely to perform brief test operations during long work periods. This means that even after long continued work and after sleep deprivation the individual can "mobilize his energies" and often do as well on a quick test as when rested.

In the reading experiments under consideration, however, this type of emergency mobilization was not possible. The samples of work used in the statistical analyses of performance in this study were chosen in an objective way after the full records were complete. Thus none of the factors which are alleged to be responsible for the summoning of special energies to meet sudden tests were available when the work samples of reading were taken. At that time the records were made and neither subject nor experimenter could know which work samples were to be selected as "tests" since the total work record was recorded.

The study of reading in relation to fatigue is important because of the significance of this process in civilized life. In the experiments discussed here a study was made of all possible changes in the motor pattern of the eyes during six-hour work periods. If any change in the visual system had developed in this period it seemed clear that a work decrement could be discovered in the eye movements as recorded. This record would then make it possible also to work out correlations if present with subjective feelings of fatigue as reported during prolonged reading.

The method of electrically recording eye movements described in the Carmichael and Dearborn

* This paper, illustrated with Kodachrome motion pictures, was presented at the meeting of the Section on November 19, 1951.

† President, Tufts College and Director of the Laboratory of Sensory Psychology and Physiology at Tufts.

reference was used. A kodachrome motion picture film was also made to illustrate the way in which movements made by the eyes during reading can be recorded so that such activity can later be used for quantitative study.[3]

The logic behind a study of changes in eye movements during long periods of activity is similar to the logic employed in studying the effectiveness of an internal combustion engine by continuous recordings of brake horsepower. In the study of the performance of such a motor it is clear that alterations in fuel or ignition will show their effects in changes in the work done by the motor. Similarly, in the case of eye movements, if fatigue renders the mechanism of reading less effective at any point in the receptor-neuro-muscular chain it is certain that this will demonstrate itself in alteration in the recorded pattern of eye movements. If deleterious retinal fatigue or brain fatigue, for example, takes place it would change the record as made. If such recorded change or work decrement is demonstrated then it would be possible, by controlling variables in the situation, to isolate the factors which are responsible for the change. Illumination, styles of type, and similar factors could also be studied in this way.

As a background for understanding the present experiment it may not be inappropriate to point out that reading in its complete form is a very complex human act. Ordinarily the following processes are necessary in order that it can be said that an individual is reading: (1.) Radiant energy (light) of such character as to provide directly or through differential reflection (as in print on paper) gradients of energy difference on the sensitive retina of the human eye. (Such gradients related to symbols, letters, words, or sentence patterns.) (2.) Differential stimulation of the retina initiating differential patterns of nerve impulses which pass into the brain centers related to eye movements and to the processes of perception and the other activities basic to reading and the comprehension of reading in the individual who has "learned to read." (3.) Controlled motor nerve impulses passing out from the central nervous system and directing the character and extent of the eye-muscle movements necessary in reading. (4.) All those processes related to motivation which determine the individual's desire to read and his determination to continue reading.

In the experiments under discussion here the materials to be read were presented both as books and as projected microfilm pages. The two books used both directly and in projection were Adam Smith's "Wealth of Nations, Vol. II" and "Lorna Doone," by Richard Blackmore.

Detailed study of the records made in the experiment indicated no statistically significant alterations indicative of fatigue in any group of subjects during the six-hour period. An analysis of these results shows that the motivation, or self-directed "urge to read and read well," of the subjects was important in yielding the results that were secured. It should also be noted that in these experiments the subjects were paid for the completion of the task. They were also given multiple-choice questions related to practically every page in the reading at the end of each twenty pages. Other tests of comprehension were also given. Thus all reading was done carefully and with the expectation that it would be the basis of an immediate examination. These procedures together with the general acceptance by the subjects of the importance of the experiment seem to have led them to maintain a constant level of high motivation for work during the six-hour period. The subjects did report some unpleasant feelings of fatigue however.

In a previous reading experiment in which examinations had not been introduced and in which the subjects were less highly motivated, it was found that before four hours were over most subjects began to skip, to look about the room, and to show other characteristic objective signs of fatigue. In these earlier experiments a curve showing a work decrement could be drawn.

A basic conclusion of the reading experiments here considered is, therefore, that if one is to read for a long period of time without showing signs of fatigue it is necessary to provide sufficient motivation to make the reading process continuous and effective. There was no significant difference between the "dull" book ("Wealth of Nations") and the "interesting" book ("Lorna Doone").

In these experiments it was also found that one can read microfilm without fatigue although with not quite the same efficiency as the printed page.

One special significance of these experiments is that they provide an interesting approach to the understanding of the basic mechanisms of continuous human work. The point to be emphasized is that in these reading experiments there was no opportunity for special motivation to bring about spurts of activity which are not typ-

ical during so-called interpolated tests. This latter criticism is appropriate in the evaluation of some of the other Tufts College studies of fatigue mentioned at the start of this paper. It should be pointed out however that in the reading experiments here discussed, as in the criticized short-term interpolated work tests, motivation was continuously and not merely occasionally at a high level.

Many practical implications in industry, education, and psychiatry can be drawn from the results of investigations such as those reviewed above. The classical fatigue curve developed in the Mosso-ergograph apparatus is not typical of the way in which normal adult human subjects, at varying levels of motivation, respond in situations requiring continuous activity. Work of the sort reviewed here, indeed, points to the fact that the physiological processes underlying the two still rather ill-defined concepts of fatigue and motivation both interact in producing work records made by normal human adult subjects. Much further scientific study will be required before these two complex processes and their relationship can be fully described.

References

1. CARMICHAEL, L., J. L. KENNEDY, & L. C. MEAD. 1949. Some recent approaches to the experimental study of human fatigue. Proc. Nat. Acad. Sci. **35:** 691.
2. CARMICHAEL, L. & W. F. DEARBORN. 1947. Reading and visual fatigue. Houghton Mifflin. Boston. 1–483.
3. CARMICHAEL, L. & L. C. MEAD. 1944–45. The electrical recording of eye movements: a film. Psychol. Cinema Reg., Bull. Penn. State College, PCR75K, 16 mm. Kodachrome, 709 ft.

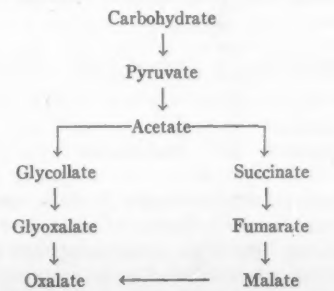
DIVISION OF MYCOLOGY

STUDIES ON LIGNIN AND LIGNIFICATION*

By F. F. NORD AND GEORGE DE STEVENS†

This paper will discuss in a general way one of the aspects of chemistry which is becoming increasingly prominent at this time, due to its relation to the processes of life and decay. The terms life and decay are especially used since the study of lignin and the mechanism of lignification cannot be divorced in any way from these essential operations. Consequently, we are touching biology, a field in which the interest lies in complexity rather than intrinsic energy. Furthermore, we are also fully aware that even a formulation of this problem is beyond the reach of any one scientist, for such a scientist would have to be, at the same time, a competent mathematician, physicist, and experienced organic chemist, and be absolutely at home in all biological disciplines. With these principles as our guide we wish to present some of our work concerning the chemistry of lignin and its possible bio-synthesis in woody tissues.

Previous work in our laboratory had demonstrated that wood-destroying molds of the "brown rot" type degraded cellulose to oxalic acid *via* acetic acid.[1] These molds selectively decay the cellulose in wood in a similar way, leaving lignin unattacked.[2] Thus, it was felt that further knowledge concerning the intermediate steps of the carbohydrate breakdown by these organisms might give significant information concerning the metabolic relationships between cellulose and lignin in plant tissues.

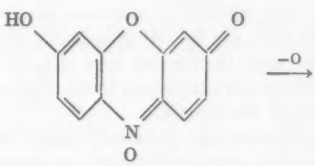


The mechanism of the formation of oxalic acid by wood-destroying molds has been established to proceed *via* a two-pronged pathway:[3]

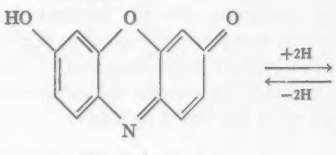
It has also been shown[4] that α-ketoglutaric acid gives rise to oxalate, *viz.*:

α-Ketoglutaric acid → succinic acid → oxalic acid.

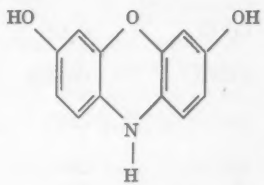
We have, therefore, studied the relationship of the dicarboxylic amino acids, aspartic and glutamic acids, to this process.[5] This investigation has been facilitated by a quantitative method for the codetermination[6] of the dehydrogenation indicator resazurin, and its reduction product resorufin.



Resazurin



Resorufin



Dihydroresorufin

This interagent possesses the advantage that it may be used under aerobic conditions, in contrast to indicators such as methylene blue.[7] It has already been used to study the course of dehydrogenation of isopropanol and sorbitol.[8, 9]

The wood-destroying molds used in the dicarboxylic acid experiments were *Trametes cinnabarina* and *Lentinus lepideus*.

It was observed that glutamate and aspartate are diverted to the synthesis of cell substance

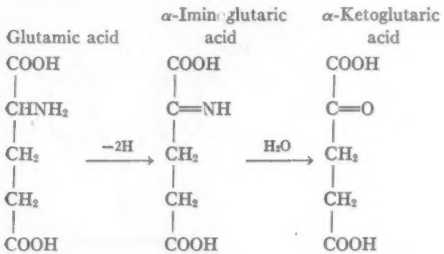
* This paper, illustrated with lantern slides, was presented at the meeting of the Section on November 23, 1951.

† Department of Organic Chemistry and Enzymology, Fordham University, New York.

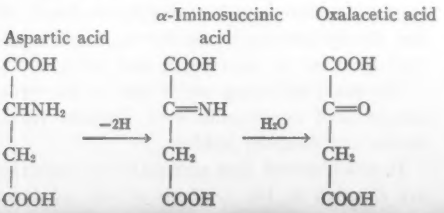
rather than to the formation of oxalate. It is not inconsistent to see α-ketoglutarate being formed from glutamate, while no oxalacetic acid can be detected in the medium containing the aspartate, as the oxalacetic acid is known to be extremely unstable.[10, 11, 12] The relatively low yields of oxalic acid derived from glutamic and aspartic acids, respectively, are probably due to the fact that the substrates must also serve as material for the synthesis of the protoplasm, and, in addition, are utilized in the metabolic activities of the molds.

The metabolism studies with cyanide present, showed no dehydrogenation whatsoever of the substrate. It is thus considered likely that the resazurin and the resorufin interact with some metal-bearing system, possibly the cytochromes active in the hydrogen transfer. Although the resazurin (or resorufin) may interact in a system several steps removed from the dehydrogenation of the particular substrates, the relative rates of reduction of the indicator are still parallel to the relative oxidation rates of the substrates.

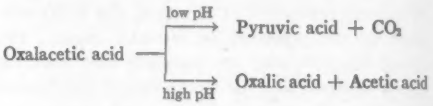
It was also observed that glutamate appears to be dehydrogenated more rapidly than succinate. If the first dehydrogenation step in the dissimilation of glutamate were the succinate-fumarate conversion, then the dehydrogenation of glutamate could not be more rapid than that of succinate. Thus glutamate is directly dehydrogenated and appears to be converted as follows:



Aspartic acid appears to be dehydrogenated in the same manner:

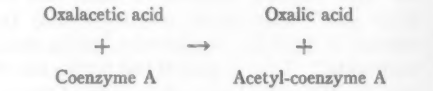


The formation of oxalacetic acid by dehydrogenation implies that this acid may be dissimilated by two mechanisms. It is known[10, 11] that oxalacetic acid is subject to decarboxylation under acid conditions, and that higher pH is favorable to its stability. Thus, alkaline media enable the acid to remain unchanged long enough to be split, yielding acetate and oxalate, while acidic media cause decarboxylation.

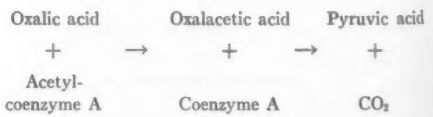


This offers an explanation for the frequently noticed effect of alkalinity in the accumulation of oxalate.

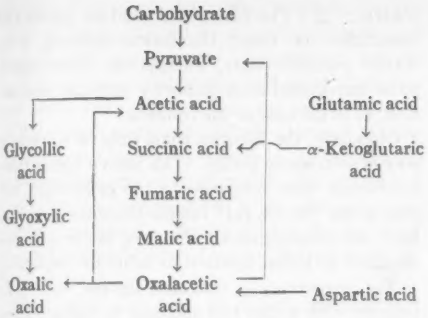
Another observation on oxalate formation is that other α-keto acids, such as oxalsuccinic acid[13] and α-ketoglutaric acid[4] do not seem[14] to yield oxalate directly but only indirectly. This appears to be due to the fact that only oxalacetic acid can function as an acetate donor. In this connection, the intervention of coenzyme A may be considered, since it is reported to function in the acetylation of sulfanilamide and choline,[15] and recently was shown[16] to take part in the enzymatic synthesis of citric acid. This concept may be illustrated as follows:



Moreover, an explanation can now be offered for the disappearance of oxalic acid from culture media.[3, 17] This involves a reversal of the above reaction, followed by decarboxylation of oxalacetate.



These considerations allow for cyclic mechanism to occur in the formation of oxalic acid, where oxalacetic acid either yields oxalate and acetate, which may be reoxidized, or pyruvate, which will then in its turn yield acetate. This is illustrated in the following phase sequence of oxalate formation by these organisms.



Much of the difficulty involved in studying the chemistry of lignin can be attributed to the fact that, for almost a century, no method was known by which lignin could be isolated in an unchanged form. Whatever method was employed, a lignin preparation was obtained which was no longer identical with lignin as it exists in nature. Recently this difficulty was removed by Brauns' extraction of lignin from certain woody tissues by means of the chemically inert solvent, ethyl alcohol, at room temperature.[18] This lignin was termed native lignin. However, the failure of approximately 97 per cent of the lignin present to be so extracted led some workers in the field to believe that either this native lignin was not identical with the bulk of the lignin or that the non-extractable lignin was chemically associated with the cellulose in the wood.[19]

Thus, these findings suggested the possibility for the utilization of cellulolytic enzyme systems as a convenient method for the isolation of additional amounts of unaltered lignin from wood.

Accordingly, the softwood, white Scots pine, was extracted with ethyl alcohol until the native lignin fraction was completely removed. The yield of this native lignin was approximately 3 per cent of the wood. The extracted wood was then infected with the "brown rot" fungi *Poria vaillantii* and *Lenzites sepiaria* and the chemical effects of decay of the wood by the molds were progressively followed by periodic analyses of the resulting wood residues. Thus from TABLE 1 it can be seen that the net action of the wood-destroying molds is indeed a depletion in the cellulose content of the wood, concomitant with an increase in the relative content of lignin.

As a result of cellulose depletion, the yield of alcohol-extractable lignin isolated from the *Poria vailantii*-decayed wood now amounted to 22.7 per cent of the residual lignin, while that from the *Lenzites sepiaria*-decayed wood corresponded to 18.3 per cent.

The native and enzymatically liberated lignins from this softwood were found to be identical with respect to elementary composition, methoxyl content, acetate and phenylhydrazone derivatives, and also to give identical ultraviolet and infrared absorption curves.

These studies revealed quite conclusively that the native lignin from white Scots pine is identical with the enzymatically liberated lignin and, therefore, all the lignin present in this softwood is a uniform chemical entity.[20]

In view of our findings with softwood lignin, it was deemed of interest to extend these investigations to several typical hardwoods; oak, birch and maple being chosen for our study.

TABLE 1

EFFECTS OF THE ACTION OF *Poria vaillantii* AND *Lenzites Sepiaria* ON THE COMPOSITION OF WHITE SCOTS PINE WOOD

Organism	*Period of Decay (mo.)*	*Cellulose per cent*	*Lignin per cent*
Poria vaillantii	0	45.5	33.9
	3	45.4	34.9
	5	33.4	42.1
	8	25.6	46.5
	11	17.6	51.1
	15	15.2	52.5
Lenzites sepiaria	0	45.5	33.9
	3	39.9	37.9
	6	30.1	41.0
	9	19.5	45.6
	13	18.5	50.1

It has been claimed that hardwood lignin differs from softwood lignin in that the former contains a methoxyl content of about 20% due to the presence of guaiacyl and syringyl nuclei; whereas softwood lignin contains only guaiacyl nuclei, thus accounting for a 15 per cent methoxyl content.

All three of our hardwoods gave a positive Mäule test,[21] which is specific for the presence of syringyl groups,[22] and each yielded a Klason lignin[23] with a methoxyl content of about 20 per cent. Yet the native lignin fractions of oak and birch were found to resemble more closely the softwood lignins; their methoxyl contents being 14.8 per cent and 14.9 per cent respectively. This similarity is extended to their ultraviolet and infrared absorption spectra.

Furthermore, like softwood lignins, the native lignins from oak and birch did not respond to the Mäule test, whereas maple native lignin, with a methoxyl content of 17.4 per cent, gave a positive

color reaction. The presence of a syringyl nucleus in this sample is further established by the sharp absorption band in its infrared spectrum at 870 reciprocal centimeters.[24, 25]

The native lignins of white Scots pine, oak, birch and maple, and the native lignin of white Scots pine obtained after decay by *Lentinus lepideus* were then chemically compared.[26] The lignins were methylated with diazomethane and oxidized with nitrobenzene and alkali.[27] The sound and decayed white Scots pine lignins were found to contain the same number of methylatable groups, further substantiating their identity. The hardwood native lignins contained more methylatable groups than the softwood lignin, and only maple native lignin yielded syringaldehyde upon oxidation.

SCHEME 1

Carbohydrate ⟶ Immediate Precursor

↓

Residual Lignin ⟵ Native Lignin

(OCH_3 = 20 per cent) (OCH_3 = 15 per cent)

TABLE 2

COMPARISON OF NATIVE AND ENZYMATICALLY LIBERATED HARDWOOD LIGNINS

	Oak		*Birch*		*Maple*	
Per cent	N.L.[a]	E.L.[b]	N.L.	E.L.	N.L.	E.L.
C	58.6	58.4	61.4	61.6	61.0	61.3
H	5.3	5.2	5.5	5.6	5.6	5.5
MeO	14.8	14.6	14.9	14.8	17.4	17.8
Phenylhydrazone MeO	13.7	13.6	13.1	13.4	15.5	15.8
Acetate MeO	10.2	10.3	10.2	10.4	12.8	12.9
Diazomethane-methylated lignin MeO	25.0	24.8	26.0	25.8	23.6	23.9
Oxidized lignin Vanillin	21.3	20.9	18.6	19.1	17.2	16.9
Syringaldehyde	nil	nil	nil	nil	4.5	4.2

[a] Native lignin.
[b] Enzymatically liberated lignin.

These findings prompted for consideration the following two relationships between the native and non-extractable residual lignins in hardwoods:[28] (1.) The native lignin and the residual lignin are essentially different: the extractable native lignin representing a transient phase in the process of lignification, originating from the carbohydrate of the cell and arising from some immediate precursor. This might serve as a substrate for an enzymatic conversion into the residual lignin, identifiable by its higher methoxyl content. (2.) The native and residual lignins are essentially the same: the former existing in a readily available state, whereas the latter seems to be surrounded more firmly by surfacial association, as is the case in the conifers.

Obviously, the dilemma could only be solved by way of enzymatic decay. The native lignin free-hardwoods were subjected to the cellulolytic action of the "brown rot" fungus *Daedalea quercina*, for a ten month period. Each of the woods was enriched in lignin relative to cellulose depletion.

The enzymatically liberated lignins were then isolated with a two fold increase in yield. Each was chemically compared with its respective native lignin fraction.

However, it must be remembered that the Klason lignins from the hardwoods had a methoxyl content of about 20 per cent. Therefore, it cannot be stated unequivocally that all the lignin present in these hardwoods is the same chemical entity.[28]

TABLE 3

COMPARISON OF BAGASSE NATIVE LIGNIN WITH LIGNINS OBTAINED BY CHEMICAL TREATMENT

	Per cent		
Bagasse lignins	C	H	OCH_3
Native (N.L.)	61.5	5.7	15.3
72 per cent H_2SO_4	60.8	5.7	15.0
10 per cent Alkali	62.9	5.7	17.0
Fuming HCl	53.4	5.7	8.8

Since our method of mold growth at the expense of the cellulose present provided an excellent and novel procedure for the isolation of additional amounts of native lignin from perennial plants, it prompted consideration of investigating the cellulose and lignin present in bagasse, the supporting fiber of the annual plant, sugar cane.

Bagasse native lignin[29] was isolated in 0.4 per cent yield and its chemical composition was compared with bagasse lignin[30, 31] obtained with the aid of strong chemical reagents. The results of this comparison are recorded in TABLE 3.

In order to ascertain which of these preparations most closely resembled bagasse lignin as it exists *in situ*, bagasse was inoculated with the mold, *Poria vaillantii*, and the chemical effects of decay over an eight month period were analytically determined.

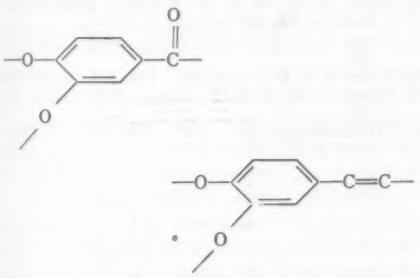
It was gratifying to determine that cellulose decay in this case proceeded at a much faster rate than with softwoods and hardwoods. After three months of decay, approximately 30 per cent

of the cellulose was degraded. Furthermore, the yield of lignin isolated by alcoholic extraction of the decayed bagasse now amounted to 3.3 per cent, an increase of approximately eight times over and above that obtained from the sound material.

The native and enzymatically liberated bagasse lignins were found to be soluble in the usual lignin solvents, to respond to the same color tests, and their chemical compositions to be identical in all respects examined. The identity of the two samples is further elaborated in their infrared absorption spectra.[29]

Ultraviolet spectroscopic studies demonstrated (1) that the native lignins from sound and decayed bagasse are indeed identical; and (2) that it has a molecular constitution somewhat different from other lignins heretofore studied.[18a, 20a,b, 25, 32]

Our sample shows a plateau between 282 and 295 mμ, and maximum absorption at 315 mμ. The absorption in the region above 300 mμ can be attributed to the presence of a chromophore group conjugated with a phenoxy ring.[33, 34, 35] Therefore, we postulate that one or any of the following building stones is present in bagasse native lignin:



However, these considerations did not necessarily exclude the possibility of the presence of a syringyl type nuclei in our sample. On the contrary, since it was found that bagasse and its native and enzymatically liberated lignin fractions gave a positive Mäule color reaction, the presence of such a building stone seemed very likely. Oxidation studies with nitrobenzene and alkali verified this contention. Moreover, the native and enzymatically liberated lignins yielded equal amounts of vanillin and syringaldehyde upon oxidation.

Thus, it can be concluded that in bagasse, as in some other woods studied, all the lignin present therein is a uniform chemical entity and that the native or the enzymatically liberated lignin fraction is representative of this entity.

Finally, TABLE 4 presents a comparative chemical evaluation of the native lignins from white Scots pine, maple and bagasse.

As to the problem of the mechanism of lignification, many speculations have been made but experimental facts have been sorely in need.

When elucidating mechanisms underlying particular functions of certain microorganisms and data, we will have to deal with certain phenomena which we, once again (for the sake of simplicity), commonly call life and decay. Their purpose is not to avoid critical points of difficulty by allusions to mysteries beyond human comprehension, but as a guide to systematic research in the future. In other words, we will deal, according to Y. M. Goldschmidt, in certain realms of the "biosphere"

TABLE 4

COMPARISON OF NATIVE LIGNINS FROM BAGASSE, WHITE SCOTS PINE AND MAPLE

		Native lignins White Scots	
Per cent	*Bagasse*	*Pine*	*Maple*
C	61.5	64.0	61.0
H	5.7	6.3	5.6
OCH_3	15.3	14.5	17.4
OCH_3 of acetate	13.3	1[illegible].1	12.8
OCH_3 of phenylhydrazone	14.1	13.3	15.5
Oxidation products:			
Per cent			
Vanillin	17.8	19.5	17.2
Syringaldehyde	13.3	nil	4.5

as it consists materially of the group of complex organic compounds.

Our work seems to have demonstrated that the "brown rot" mold, *Lentinus lepideus*, produces methyl-para-methoxy cinnamate when carbohydrates or ethyl alcohol serve as substrates.[36] The key intermediate in the enzymatic formation of the ester was found to be acetaldehyde.[37] It has also been shown that this mold causes the formation of the ester when grown on pine wood. Thus, the experimentally evidenced formation from carbohydrates of a methoxylated aromatic compound, then gives us some insight into the possible mechanism of conversion of the carbohydrate constituents of wood into lignin.[38, 39]

In conclusion, we feel that the identity of the native lignin and the enzymatically liberated lignin of some woods, as previously described, in conjunction with Mühlethaler's electron microscope

studies[40] on wood, makes improbable the presence of a chemical linkage between cellulose and lignin. Moreover, these studies have demonstrated that the native lignin is representative of all the lignin present in woody tissues and consequently, any future chemical studies designed to unravel the true structure of lignin, should be done with native lignin.

Bibliography

1. Nord, F. F., & L. J. Sciarini. 1946. Arch. Biochem. **9:** 419.
2. Birkinshaw, J. H., W. P. K. Findlay, & R. A. Webb. 1940. Biochem. J. **34:** 906.
3. Nord, F. F., & J. C. Vitucci. 1948. Adv. in Enzymol. **8:** 253.
4. DeBaun, R. M., S. F. Kudzin, & W. J. Schubert. 1950. Arch. Biochem. **26:** 375.
5. de Stevens, G., R. M. DeBaun, & F. F. Nord. 1951. Arch. Biochem. Biophys. **33:** 304.
6. DeBaun, R. M., & G. de Stevens. 1951. Arch. Biochem. Biophys. **31:** 300.
7. Thunberg, T. 1920. Skank. Arch. Physiol. **40:** 1.
8. Vitucci, J. C., E. Sodi Pallares, & F. F. Nord. 1946. Arch. Biochem. **9:** 439.
9. Smith, V. M. 1949. Arch. Biochem. **22:** 287.
10. Straub, F. B. 1936. Z. physiol. Chem. **244:** 117.
11. Krebs, H. A. 1942. Biochem. J. **36:** 303.
12. Allsopp, A. 1937. New Phytologist **36:** 327.
13. Lynen, F., & F. Lynen. 1948. Ann. **560:** 149.
14. Weinhouse, S., & K. F. Lewis. 1951. J. Am. Chem. Soc. **73:** 2906.
15. Lipmann, F. 1950. The Harvey Lectures, Series XLIV: 99.
16. Stern, J. R., B. Shapiro & S. Ochoa. 1950. Nature **166:** 403.
17. Müller, H. 1950. Arch. Mikrobiol. **15:** 137.
18. a. Brauns, F. E. 1939. J. Am. Chem. Soc. **61:** 2120.
    b. Brauns, F. E. 1945. J. Org. Chem. **10:** 211.
19. Wald, W. J., P. F. Ritchie & C. B. Purves. 1947. J. Am. Chem. Soc. **69:** 1371.
20. a. Schubert, W. J. & F. F. Nord. 1950. J. Am. Chem. Soc. **72:** 977.
    b. Schubert, W. J. & F. F. Nord. 1950. *ibid.* 3835.
21. Mäule, C. 1900. Beiträge wiss. Bot. **4:** 166.
22. Campbell, W. G., J. C. McGowan & S. A. Bryant. 1938. Biochem. J. **32:** 2138.
23. Ritter, G. J., R. M. Seborg & R. L. Mitchell. 1932. Ind. Eng. Chem. Anal. Ed. **4:** 202.
24. Jones, E. J. 1949. Dissertation, Institute of Paper Chemistry, Appleton, Wisconsin.
25. Kudzin, S. F. & F. F. Nord. 1951. J. Am. Chem. Soc. **73:** 690.
26. Kudzin, S. F., R. M. DeBaun, & F. F. Nord. 1951. Ibid. **73:** 4615.
27. Freudenberg, K. & W. Lautsch. 1939. Naturwiss. **27:** 227.
28. Kudzin, S. F. & F. F. Nord. 1951. J. Am. Chem. Soc. **73:** 4619.
29. de Stevens, G. & F. F. Nord. 1951. Ibid. **73:** 4622.
30. Hachihama, Y. & H. Saegusa. 1934. J. Soc. Chem. Ind. Japan. **37** (suppl. binding): 771.
31. Payne, J. H., E. Fukunaga & R. Kojima. 1937. J. Am. Chem. Soc. **59:** 1210.
32. Jones, E. J. 1949. TAPPI, **32:** 311.
33. Hillmer, A. & P. Schorning. 1934. Z. physik. Chem. **168A:** 81.
34. Morton, R. A. & A. L. Stubbs. 1940. J. Chem. Soc. 1947.
35. Pearl, I. A. & D. L. Beyer. 1951. J. Org. Chem. **16:** 216.
36. Nord, F. F. & J. C. Vitucci. 1947. Arch. Biochem. **14:** 243.
37. Nord, F. F. & J. C. Vitucci. 1947. Ibid. **15:** 465.
38. Fiore, J. V. & F. F. Nord. 1949. Ibid. **23:** 473.
39. Fiore, J. V. & F. F. Nord. 1950. Ibid. **26:** 382.
40. Mühlethaler, K. 1949. Biochim. Biophys. Acta. **3:** 15.

THE ISOLATION OF PLANT RUSTS UPON ARTIFICIAL MEDIA AND SOME SPECULATIONS ON THE METABOLISM OF OBLIGATE PLANT PARASITES*

By VICTOR M. CUTTER, JR.†

The Uredinales have long been considered strict obligate parasites of the higher green plants, and attempts to culture members of this group on artificial media have met with little success. Their parasitism is so strictly obligate that death of the infected host cell usually results in the immediate death of the rust mycelium infecting that cell. Only the resistant spores of these fungi are capable of an independent non-parasitic existence, and even this independence is rapidly terminated on germination of the spore unless a compatible host cell is encountered by the germ tube. Much information has accumulated about the factors governing germination of the rust spores and the conditions under which infection will occur, but practically nothing is known about the specific metabolites which these parasites obtain from their hosts.

The recent report by Hotson and Cutter[10] on the isolation and culture of the rust *Gymnosporangium juniperi-virginianae* upon synthetic media, and particularly their discovery that the isolated cultures of this rust showed no unusual nutritional requirements which might explain its obligate parasitism, has refocused attention upon this problem. The approach used in this successful isolation of *Gymnosporangium* was predicated on the assumption that it might be possible to condition the rust mycelium to a saprophytic mode of existence by initiating undifferentiated tissue cultures of rust-infected plant organs on artificial media and ultimately so changing the environmental conditions to which this rust-host tissue complex was exposed that independent growth of the rust might be induced. Since the details of this work have already been published they will not be reiterated here. To date, four strains of *G. juniperi-virginianae* have been isolated from the telial host *Juniperus virginiana* and have been tested by reinoculation into the alternate host *Crataegus sp.* In all cases these strains have been maintained by repeated subculture upon artificial media for at least six months without loss of their ability to reinfect the alternate host.

While detailed metabolic studies of these isolated strains are not yet complete, it appears that they are autotrophic for all the known vitamins with the exception of biotin: they can utilize a fairly wide range of sugars and polyhedric alcohols as carbon sources, and a number of organic and inorganic nitrogenous compounds are metabolized and can serve as sole nitrogen sources. We are faced, therefore, with the anomalous situation of a strict obligate parasite, after a period of conditioning in relatively undifferentiated host tissue under artificial conditions, suddenly becoming saprophytic. This might be understandable on the basis of the adaptation, under these conditions, of a precise nutrient requirement to a somewhat less precise requirement, except for the fact that to date it has not been possible to carry out this transformation consistently with identical material under closely controlled conditions. In the very large number of attempts made, the rust fungus has been successfully isolated in only four cases, and in all these the rust finally achieved saprophytic status only after four to six months of association as a parasite upon the host tissue culture. Furthermore this transformation was preceded by a period in which the rust mycelium became pathogenic and destroyed the host tissue before beginning independent growth. In short, the rust in culture first behaved as an obligate parasite, then became pathogenic and finally began to manifest saprophytic tendencies. Upon reinoculation into its alternate host, following a period of culture as a saprophyte, it again behaved as an obligate parasite. It appears from the results of these experiments, full details of which will be published at a later date, that this transformation does not occur regularly and may result from the selection or mutation of only a few rust cells or nuclei out of the whole population in a rust-host tissue culture.

Very little direct evidence concerning metabolic pathways in the obligate plant parasites has been obtained due to the difficulties of separating host and parasite reactions. Certain facts have nevertheless been reported which in the light of the behavior of these isolates of *Gymnosporangium* suggest a hypothesis concerning the specific metabolites which the plant rusts obtain from their hosts. The known factors involved in the germi-

* This paper, illustrated with Kodachrome slides, was presented at the meeting of the Section, November 23, 1951.

† Osborne Botanical Laboratory, Yale University, New Haven, Conn.

nation of rust spores shed very little light on this problem since the various spores of these parasites will apparently germinate whenever environmental conditions are favorable, without any particular relation to the nutritional elements of the substrate.[9] We can therefore pass on to those factors influencing infection. In this instance we will consider infection as the actual establishment of a mutualistic interrelationship of host and parasite; involving the formation of intercellular rust mycelium within the host, the development of intracellular hausatoria by the cells of the fungus, and the appearance of those disturbances in the metabolic behavior of the host cells which are characteristic of the particular species of rust and host.

It has been known since the time of Marshall Ward[23] that light plays an important part in the establishment of rust infection. Green plants inoculated with rust spores and placed in the dark did not become infected whereas similarly inoculated plants placed in the light were heavily parasitized. The experiments of Mains[14] on many species of rust and of Trelease and Trelease[22] on *Erysiphe graminis* confirmed these observations and indicated that the presence of carbohydrates in the host cells was also necessary to the establishment of infection, since detached leaves of plants kept in the dark and supplied with carbohydrates were susceptible to infection. These authors also emphasized the vital nature of the photosynthetic reaction by showing that, even in the light, rust infection did not occur in an atmosphere devoid of carbon dioxide. It was soon apparent, however, that some other factor in addition to carbohydrates was being synthesized during the light reaction of photosynthesis. Both Mains and Fromme[7] pointed out that a dark period following inoculation retarded the subsequent development of rust infection in the light by approximately the same length of time as the duration of the dark period. Under these conditions it was obvious that sufficient reserve carbohydrate would be present in the host cells to permit infection, were carbohydrates the only metabolites required by the rusts.

In a very extensive series of experiments involving rust infection under various conditions of intermittent light, Forward[6] showed that in darkness rust infection was retarded or eliminated even in the presence of carbohydrates, and when it did occur the infection type tended towards the so-called immune reaction of Stakman and Levine.[19] Under intermittent illumination at various intensities, even though the intensity was so low that the accumulation of carbohydrate must have been greatly reduced, the rust infections were perfectly comparable with those on continuously light-grown plants. These data suggest the light-conditioned synthesis of an unstable accessory compound required by the rust in green plant cells.

Considerable evidence has also accumulated, in the work of Waters,[24] Melander[15] and Doran,[4] that while temperature is not the determining influence in the establishment of infection, the type and course of infection may be very greatly influenced by the prevailing temperatures. Again, we might postulate from this the dependence of the rust upon a relatively unstable metabolite.

In an attempt to gain further insight into the nature of this light-synthesized factor, the author carried out several previously unpublished experiments on the ability of rusts to infect albino plants. Aeciospores of *Puccinia sorghi*, collected from plants of *Oxalis sp.*, were inoculated onto the first two foliage leaves of albino seedlings of *Zea mays* and on normal green seedlings of the same strain under greenhouse conditions. The albinos of this strain of corn do not produce any chlorophyll. In all cases the only evidence of infection on the albino seedlings was a slight hypersensitive flecking whereas the green seedlings were heavily infected. A similar experiment involved inoculation of virescent corn seedlings where chlorophyll was present in low concentration compared to the normal green alleles. The virescents in this case showed much weaker infections than the normal green seedlings.

Albino, virescent and normal green seedlings were then grown in sterile agar cultures in flasks upon Hoagland's nutrient solution with two per cent dextrose added and again inoculated. Duplicate cultures of all three types were kept in light and dark. In the light-grown flasks the albino seedlings showed hypersensitive flecking, the virescents weak infection, and the greens heavy infection. In the dark-grown flasks the albinos gave no evidence of any infection, the virescent seedlings showed hypersensitive flecks, and the green seedlings developed weak but characteristic infection. It is apparent therefore that whatever

the required infection factor may be it is associated with the presence of chlorophyll and may bear a quantitative relationship to the amount of chlorophyll present.

To determine whether this factor was capable of diffusion or translocation from cell to cell, another experiment was designed. A variegated plant of *Geranium maculatum* Linn. which had been propagated for some years in a garden near Ithaca, N. Y. was subdivided, and the offsets potted and brought into the greenhouse. When new leaves had developed on the offsets, those showing large chlorophyll deficient areas were heavily dusted with teliospores of *Puccinia polygoni-amphibii*, from *Polygonum persicaria* L. and the plants were placed under bell jars in a saturated atmosphere in the light. Pycnial infections occurred on most of the inoculated leaves and in all cases were confined to the green areas of the leaves. The colorless or virescent portions of the leaves showed no evidence of infection. This would indicate that whatever factor was being synthesized in the green areas of the leaf was not diffusing into the chlorophyll deficient areas.

Extensive respiratory measurements of wheat leaves infected with the obligate ectoparasite *Erysiphe graminis*, and of the detached parasite, led Allen and Goddard[3] to suspect the presence of a diffusible compound which stimulates the hydrolysis or activation of carbohydrates, or their intermediates, in the area immediately adjacent to the infection court. This substance, apparently produced by the fungus, markedly stimulates aerobic respiration in infected wheat, and the evidence presented indicates clearly that the increased activity occurs in host cells which have not actually been invaded by the parasite. On removal of the parasite from its host there is a rapid decrease in respiratory activity in both host and parasite. The nature of this compound is still hypothetical but it might logically be presumed to be a phosphorylase secreted by the fungus.

Humphrey and Dufrenoy[11] studying the cytology of the host parasite relationship in *Avena*, infected with *Puccinia coronata*, by the use of a molybdenum reagent, made a notable contribution to our knowledge of the phosphorylated compounds present in the infection court. It is claimed that the degree of phosphorylation of various compounds is indicated by the rate and intensity of their reaction with this reagent to form blue phospho-molybdenum deposits. Prior to germination in uredospores of *P. coronata* there is a high concentration of strongly bound phosphorus. Upon germination this reserve is presumably remobilized and functions in the growth and development of the germ tube; but after it is again bound into energy-rich linkages in the germ tube and accessory structures, the rust becomes dependent upon its host for all the phosphorus needed by the developing mycelium. Examination of infected areas stained with the molybdenum reagent bring out the fact that these infected tissues release phosphorus compounds into the intercellular spaces. As a result, gradients of phosphorus concentration are set up through the infected portions of the plant with a resulting translocation of phosphorus towards the infection court. Since these compounds may be translocated as phosphorylated sugars, the residue might be deposited as glucose, sucrose and starch in the vicinity of the infection, while the phosphorylated intermediates are utilized by the developing fungus. Allen[2] has shown that such an accumulation of carbohydrate reserves occurs in the infection court, and the degradation of phosphorylated compounds (phospholyse) can be demonstrated cytogically in this area. The staining reaction of the infected areas of the host suggest that there is a high concentration of phosphorylated sugars in the immediate vicinity of the rust mycelium during its development, and from Allen's data it appears highly probable that phospholyse is accomplished by phosphorylases secreted by the parasite.

Gottlieb and Garner[8] have bolstered the concept that phosphorylated compounds accumulate in the rusted areas of leaves by tracing the distribution of radioactive phosphorus (P^{32}) in infected and non-infected leaves. While the overall phosphorus content of infected and non-infected leaves is comparable, there is a marked concentration of radioactive phosphorus in the infection courts of rusted leaves and the greatest concentration appears to be in the cells of the host rather than in the rust mycelium and spores. That this accumulation is not merely the result of increased translocation in response to injury is indicated by the fact that the accumulation can be demonstrated very shortly after infection occurs and before any cellular damage or rupturing of the host epidermis has occurred.

The importance of high concentrations of carbohydrate and phosphorus compounds in rust me-

tabolism is further emphasized by some observations of Hurd-Karrer and Rodenhiser[12, 17] In a synthetic medium with unusually high concentrations of hexose sugar and inorganic phosphate, the germ tubes of a number of cereal rusts develop structures quite reminiscent of the appressoria and substomatal vesicles which these organisms form on their hosts. Under these conditions, curious fusion bodies are also frequently developed between germ tubes. It may well be that the production of these bodies, not ordinarily seen in germ tubes developing under artificial conditions, may represent a slight ability of these rusts to synthesize their key requirements, if supplied with sufficiently high concentrations of the basic ingredients.

Similarly it has been noted, with the saprophytic cultures of *Gymnosporangium* referred to above, that in a synthetic medium (of the composition: Dextrose 5 g., NH_4NO_3 2 g., KH_2PO_4 2.5 g., $MgSO_4$ 0.25 g., Yeast extract 10 mg., H_2O 1000 cc.), the addition of 20 mg. of adenine or of adenylic acid induces much better growth and sporulation than that which occurs in the control cultures lacking these compounds. While, of course, this is not conclusive evidence of the requirement of the rust for phosphorylated esters it poses an intriguing possibility.

An entirely different line of evidence on the relation of nucleotides to rust metabolism stems from the very interesting observations of Savile[18] on a number of rusts. He points out the positive attraction of the host nucleus for the rust hausatorium, showing that almost invariably, in infected cells, the hausatorium comes to lie in juxtaposition with the host nucleus and frequently enfolds it. A further observation made by Savile with the use of a staining technique, where the reagents were buffered to the approximate isoelectric point of the infected cells, may be of considerable importance in understanding this phenomenon. The particular stains used were erythrosin and methylene blue, and under these conditions the host nucleus stains blue with red nucleoli and cytoplasm; whereas the rust nucleus stains bright red and the rust cytoplasm deep blue. In short, we have here the quite unique situation of the host nucleus staining like the parasite cytoplasm, with the rust nucleus reacting like the host cytoplasm and nucleoli. Again we have the suggestion that host nucleic acid or its degradation products may be exerting an influence on the rust, and that rust metabolism as judged by staining reaction is quite unlike that of facultative parasites. The recent report by Yarwood[25] of the increased invasiveness and infectivity of several plant viruses on rust-infected hosts also suggests a possible increase in rust-infected tissues of the materials necessary for virus synthesis, *i.e.* nucleoproteins. A similar increase in virus activity is not noted following the infection of the same hosts by facultative parasites. That this stimulation of virus infection may result from liberation or accumulation of phosphorylated nucleotides is at least worthy of speculation.

If we are to accept the possibility that the key metabolites required by rusts are phosphorylated esters or sugars, it must be further postulated that such compounds are capable of diffusion from the host cells into the rust mycelium. Most available evidence indicates that the phosphorylated nucleotides are not readily diffusible and hence might not be taken up by rust cells. We have, however, two interesting lines of evidence which suggest that the obligate parasites may be unique in their ability to extract large molecules from their hosts. The work of many cytologists[16] indicates that the hausatorial membrane in rusts is much less differentiated than the membranes surrounding the remainder of the mycelial cells. In fact it has been suggested that the hausatorium is essentially naked protoplasm. While the validity of this is open to question, Thatcher[21] on the basis of extensive studies of the osmotic concentration of rust cells and hausatoria and of the host cells which they infect, has concluded that the osmotic pressures in the rust cells are such that a strong osmotic gradient in favor of the rust will be established. It also appears probable from his data that secretions from the rust mycelium may increase the permeability of host cells in the infection court. A mechanism may therefore exist by which these phosphorylated compounds could be taken up by the obligate parasites.

From the preceding data it is difficult not to conclude that, in addition to carbohydrates and mineral elements, the rusts derive some other essential metabolite from their hosts. Whatever this particular substance may be it is obviously associated with the presence of chlorophyll and it is synthesized in light. Furthermore, it appears relatively unstable since it is not conserved during dark periods, and it does not seem to be readily diffusible. The interrelationships of carbo-

hydrates, phosphorus compounds, and possibly nucleic acids, which have been pointed out above, might implicate some of the highly labile phosphate esters as the key factors in rust metabolism. The very extensive experiments of Stock[20] and many others with various carbohydrates and mineral salts as nutrient substrates for the rusts, suggests that these obligate parasites cannot synthesize such labile esters directly from basic carbohydrates and inorganic sources of phosphate. It is also well known that these phosphate esters are present in green plants[18] and are very labile in expressed plant juices. This might explain the lack of success which various workers have had in culturing rusts upon plant extracts and autolysates. These phosphorylated compounds have only recently become available in pure form, and the author is not aware of any attempts to culture rust spores or mycelium on suitable nutrient media supplemented with any of these compounds.

The possible relation of photosynthesis to the production of phosphorylated esters has been discussed by Emerson, Stauffer and Umbreit[5] who suggest that the absorption of light energy by chlorophyll results in the formation of "energy-rich" phosphate. Albaum and Umbreit[1] have also shown that in plants grown in the light in the absence of CO_2 there is a marked decrease in the barium insoluble resistant phosphate fraction. If we were to assume a requirement for hexose-phosphate on the part of the rust, this might explain the observation that rust infection does not occur in plants grown in the light in the absence of CO_2.

Were such a requirement for phosphorylated intermediates definitely proven, we might conclude that the major difference between the metabolism of these obligate parasites and other facultative plant parasites resided in the inability of the rusts to synthesize the necessary "energy-rich" intermediates with which to carry out the phosphorylation of simple carbohydrates. From an evolutionary standpoint it seems plausible that organisms which, through mutation, might have lost certain portions of their phosphorylative mechanism could be conserved in an environment where there was an excess of the required intermediates already phosphorylated to a level sufficient for their needs. That the green plant supplies such an environment is obvious, and we need only make the further assumption that the rusts had or were able to develop a mechanism which allowed them to assimilate and continue to metabolize these intermediates. The peculiar morphological development of the rust hausatorium and the known facts concerning the osmotic behavior of the intercellular rust mycelium imply such a mechanism. The fact that among the primitive rust-like basidiomycetes a series of developments can be traced, from saprophytism through various stages of facultative parasitism to a strict obligate parasitism, provides a precedent for the idea that such mutations might have occurred and been conserved. Furthermore, the very precise physiologic specialization of the Uredinales in regard to hosts might well be traced to the deletion of different and specific portions of the phosphorylative mechanism in different rust strains.

Confirmation of this hypothesis will depend upon the performance of the critical experiments; namely, the induction of direct growth of rust mycelium upon synthetic media fortified with the required intermediates. At the present time, due to the lability of these intermediates, such experiments are fraught with considerable difficulty, but the possibility that this line of approach will yield tangible results in the artificial culture of rusts appears worthy of serious consideration.

Bibliography

1. Albaum, H. G. & W. W. Umbreit. 1943. Phosphorus transformations during the development of the oat embryo. Am. J. Bot. **30:** 553.
2. Allen, P. J. 1942. Changes in the metabolism of wheat leaves induced by infection with powdery mildew. Am. J. Bot. **29:** 425.
3. Allen, P. J. & D. R. Goddard. 1938. A respiratory study of powdery mildew of wheat. Am. J. Bot. **25:** 613.
4. Doran, W. L. 1919. The minimum, optimum and maximum temperatures of spore germination in some Uredinales. Phytopath. **9:** 391.
5. Emerson, R. L., J. F. Stauffer & W. W. Umbreit. 1944. Relationships between phosphorylation and photosynthesis in *Chlorella*. Am. J. Bot. **31:** 107.
6. Forward, D. F. 1932. The influence of altered host metabolism upon modification of the infection type with *Puccinia graminis tritici* p.f.21. Phytopath. **22:** 493.
7. Fromme, F. D. 1913. The culture of cereal rusts in the greenhouse. Bull. Torrey Bot. Club **40:** 501.
8. Gottlieb, D. & J. A. Garner. 1946. Rust and phosphorus distribution in wheat leaves. Phytopath. **36:** 557.
9. Gottlieb, D. & H. Hart. 1943. Growth substances and the rust fungi. Phytopath. **33:** 724.
10. Hotson, H. & V. M. Cutter, Jr. 1951. The isolation and culture of *Gymnosporangium juniperi-virginianae* Sch. upon artificial media. Proc. Nat. Acad. Sci. **37:** 400.

11. HUMPHREY, H. B. & J. DUFRENOY. 1944. Host-parasite relationship between the oat plant (Avena spp.) and crown rust (*Puccinia coronata*). Phytopath. **34:** 21.
12. HURD-KARRER, A. & H. A. RODENHISER. 1947. Structures corresponding to appressoria and substomatal vesicles produced on nutrient solution agar by cereal rusts. Am. J. Bot. **34:** 377.
13. JAMES, W. O. & A. H. BUNTING. 1941. On the method of glycolysis in Barley. New Phytologist **40:** 268.
14. MAINS, E. B. 1917. The relation of some rusts to the physiology of their hosts. Am. J. Bot. **4:** 179.
15. MELANDER, L. W. 1931. The effect of temperature and light on the development of the uredinial stage of *Puccinia graminis*. Phytopath. (Abst.) **21:** 109.
16. RICE, M. A. 1927. The hausatoria of certain rusts and the relation between host and pathogene. 1927. Bull. Torrey Bot. Club. **54:** 63.
17. RODENHISER, H. A. & A. HURD-KARRER. 1947. Evidence of fusion bodies from urediospore germ tubes of cereal rusts on nutrient solution agar. Phytopath. **37:** 744.
18. SAVILE, D. B. O. 1939. Nuclear structure and behavior in species of the Uredinales. Am. J. Bot. **26:** 585.
19. STAKMAN, E. C. & M. M. LEVINE. 1922. The determination of biologic forms of *Puccinia graminis* on *Triticum sp.* Minn. Agr. Exp. Sta. Tech. Bull. 8.
20. STOCK, F. 1931. Untersuchungen über Keimung und Keimschlauchwachstum der Uredosporen einiger Getreideroste. Phytopath. Zeitschr. **3:** 231.
21. THATCHER, F. S. 1939. Osmotic and permeability relations in the nutrition of fungus parasites. Am. J. Bot. **26:** 449.
22. TRELEASE, S. F. & H. M. TRELEASE. 1929. Susceptibility of wheat to mildew as influenced by carbohydrate supply. Bull. Torrey Bot. Club. **56:** 65.
23. WARD, H. M. 1902. On the relations between host and parasite in the bromes and their brown rust *Puccinia dispersa* (Erikss.) Ann. Bot. **16:** 233.
24. WATERS, C. W. 1928. The control of teliospore and urediniospore formation by experimental methods. Phytopath. **18:** 157.
25. YARWOOD, C. E. 1951. Associations of rust and virus infections. Science **114:** 127.

SECTION OF ANTHROPOLOGY

PHILOSOPHICAL ANTHROPOLOGY AND WORLD LAW*†

By F. S. C. NORTHROP‡

The need in an atomic age for settling disputes between nations by peaceful rather than violent means is obvious. History gives no evidence, as Dean Roscoe Pound has recently reminded us, that a peaceful settling of disputes in any sphere has ever been achieved without recourse to legal procedures or rules. Legal procedures and rules applied to international disputes mean a world law.

Notwithstanding this need for a world law, previous attempts to achieve it have been most disheartening. One need only recall the disillusionment following the founding of the League of Nations at Versailles, or the present cold war and vituperation supplanting the high hopes for the United Nations which were voiced and officially affirmed at San Francisco.

These discouragements suggest that perhaps we have been going about the achievement of an effective international law in the wrong way. Apparently the conditions for an effective law have not yet been met in the international sphere. It behooves us, therefore, to turn aside momentarily from the world at large to examine what legal science has to teach us about the criterion for an effective law.

This criterion, The Criterion of Effective Law, is well known to all contemporary legal thinkers. It has been laid down by the great Austro-Hungarian sociologist of law, Ehrlich, and is expressed in Ehrlich's formula that the positive law must be grounded in and correspond to the living law. By "positive law" Ehrlich means the legal constitutions, statues, institutions and officials which are introduced. By the "living law" he means the *de facto* behavior, mores and norms of the people, or at least a majority of the people, quite apart from the positive law. When the positive law is not rooted in the living law, it is Ehrlich's thesis that legal institutions and processes for handling disputes break down. The failure of the prohibition amendment in the United States, even though it was legally passed, is an instance.

Ehrlich's criterion of effective law has implications in the international sphere—implications moreover which have not received the attention which they merit. What his principle means, internationally, is that no positive legal rules or institutions for bringing the settlement of disputes between nations under the rule of law, rather than of force, can be successful unless these positive rules and institutions are rooted in, and are the expression of, the living law of all the major peoples and cultures of the world.

The first task, therefore, in the attempt to obtain an effective world legal order is to determine the underlying living law of the world's major different peoples and cultures. Clearly this is an undertaking for which the lawyer and the statesman are quite incompetent. The living law of the diverse cultures and peoples of the world can be determined only by a direct scientific study of those cultures, and the science whose business it is to pursue this study is anthropology. Hence the importance of anthropology, and in particular cultural anthropology, for world law.

But not everything with which cultural anthropology concerns itself is relevant to or necessary for the statesman's or international lawyer's purpose. Only certain factors supplied by the science of cultural anthropology are required. These relevant factors become evident when one notes that positive law is concerned always with norms. Positive law always prescribes certain normative rules, statutes or procedures which serve as a normative measuring rod to distinguish the behavior in society which is permissible from that which is not. In short, law is concerned with the normative factor in cultural and social organization. What the international lawyer needs, therefore, from the anthropologist is the normative factor in the living law of the different peoples and cultures of the world. What is wanted from the cultural anthropologist is the living, vital, indigenous ethos of each culture in the world; that living ethos which will sustain the international lawyer's positive world law providing he constructs this positive world law out of, and in accord with, this living ethos.

At least we are now able to see why the tradi-

* This paper was read at the meeting of the Section of Anthropology on November 26, 1951.
† The author is indebted to the Wenner-Gren Foundation for Anthropological Research for a grant which makes this, and other, research possible.
‡ Yale University Law School, New Haven, Conn.

tional attempts at a world legal order have been so disheartening. The positive law which defined these traditional attempts corresponded at most only to the living law ethos of but one culture in the world, the modern French and Anglo-American Western culture. It was little more than a positive law brought into correspondence with the living law of this solitary, relatively small Western culture and then generalized for the rest of the world. By the very nature of the case, such an international law fails to correspond to the plurality of living laws of the other European, Latin American, African, Islamic and Asian cultures of the world and hence, of necessity, must be ineffective.

Having noted that the first step toward an effective world law is the determination through cultural anthropology, and it may be added, through sociology, of the living ethos of each of the major cultures and nations of the world, the second task becomes evident. It becomes that of determining the key independent variable or variables in the science of cultural anthropology which, when its values are determined empirically for any specific culture, give us the ethos of that culture. What is this independent variable?

Fortunately the sciences of sociology, anthropology and psychology converge upon the specification of the answer to this question. The work of many different sociologists, anthropologists and psychologists could be brought to the support of the conclusion upon which these three sciences converge. For purposes of brevity, we shall restrict ourselves to one or two scientists for each of these three sciences. Those which we chose are Sorokin for cultural sociology, Kluckhohn for cultural anthropology and McCulloch and Pitts for neurological psychology. More specifically we shall restrict ourselves to Sorokin's concept of logico-meaningful causality, Kluckhohn's study of the legal norms of the Navaho Indians, and McCulloch and Pitts' concept of cortically trapped universals in their relation to any person's response to a stimulus.

Sorokin's Concept of Logico-Meaningful Causality. Sorokin noted that there is a difference between causality in any system of natural science and causality in any system of cultural science. Whereas the former is mechanical, causality in cultural science is logico-meaningful.

The mechanical causality characterizing the systems of nature is illustrated in Newtonian mechanics, Einstein's theory of relativity and Schroedinger's quantum mechanics. These examples show that a natural system is governed by mechanical causation when an experimentally verified, deductively formulated, theory of the subject matter to which the system refers specifies independent variables defining any state of the system; and specifies such postulates that when the values of these independent variables for a specific state of the system at a given time t^1 are determined empirically, the postulates of the theory enable us to mathematically calculate, or in other words, logically deduce, the values of these independent variables for any other state of the system at any earlier or later time t^2. In the case of Newtonian mechanics, these two independent variables are but two in number: the position and the momenta of the entities of the system.

The nature of logico-meaningful causality begins to become evident when one pursues the analogy of Newtonian mechanics in the cultural sciences as far as it will go. Any natural system designated by Newtonian mechanics has its entities. They are the physical or scientific objects. The cultural systems also have their entities. They are the human persons and their physical environment. When, in Newtonian mechanics, the postulates and values of the variables defining the state of any system are specified, the ordering relations of the system are made determinate. The mere specification, however, in any cultural system of the positions and momenta of the persons in that society is not sufficient to specify the ordering relations which define the culture of those persons.

An example will suffice to make this clear. In many village communities of India, Moslems and Hindus have lived together for centuries. Most of the Moslems are converts from Hinduism, thus ethnologically the peoples are for the most part identical. Hence, the cultural differences between Moslems and Hindus which are so great as to necessitate the present division of 19th Century India into Pakistan and New Delhi's India are not to be explained by physical, ethnological differences. The momenta and positions of the bodies of the Hindus and Moslems in any single village hardly account for the differences in their two cultures. The position of Moslems and Hindus is identical since both are located in the same village. If one watched both groups walking down the street there might be slight differences in

their momenta, but hardly differences sufficient to account for the differences in culture. In fact we would suspect that where differences in momenta between Moslems and Hindus in the same village appeared, these differences would be the effect rather than the cause of the cultural differences. Clearly the cultural ordering relations are not given after the manner in which the ordering relations of natural systems exhibiting their mechanical causation are given.

What is the unique factor, in addition to the aforementioned physical factors, which must be determined in order to make the ordering relations, which incidentally define the ethos of a culture, determinate? Sorokin's answer is that this additional key variable, unique to cultural systems, is to be found in the meanings that the persons making up any single culture hold in common and use to conceptualize, order and integrate the raw data of their experience. It is because meanings are the key factor that Sorokin calls this unique causality of cultural science "logico-meaningful causality."

What this entails is that wherever there are two different cultures, the persons in those cultures are using different basic meanings or concepts to describe, systematize and integrate the data of their experience. The Hindus in the Indian villages are using those of Hinduism; the Moslems, those of Islam; and so we could go on beyond the Hindu villages to the rest of the world. Then we would say Soviet Russians are using those of Marx as interpreted by Lenin and Stalin. The traditional Chinese, those of Confucius; the Siamese, those of Buddhism, with a slight top layer of Hinduism; the Roman Catholics those of St. Thomas; the Americans those of Locke and Jefferson and Adam Smith and Mill and Jevons, and more recently Keynes.

Our example of the Indian village suggests also another point noted by Sorokin. The meanings used by a given people to describe, organize and interpret the data of their experience determine the ethos of their culture. I would even go further and say that they are its ethos. The word "good" is literally nothing more than the name for the basic meanings of the hierarchy of all meanings used by a people to conceptualize themselves and their universe. This follows from what has been said. For if the basic meanings define the ordering relations of a culture, they automatically define its living law, and the living law of a culture is its ethos. To these basic conceptual meanings the word "good" adds but one thing in addition to its designation of them, *i.e.*, their application to, and use as a measure of, conduct. In short, ethics is the conceptualization of the data of experience applied.

But what are the basic meanings of a people or culture? The traditional term used everywhere for the basic concepts of anything is philosophy. This is the reason why the international lawyer, if he is to be effective in meeting the world's present need, must go not merely to anthropology but to philosophical anthropology. This brings us to the second of our three contemporary scientists.

Kluckhohn's Philosophy of the Navaho Indians. What makes this study especially relevant is the fact that the Navaho have no written literature. None the less Kluckhohn found after years of first-hand study of them that he did not understand what he saw until he teased out of them their philosophy. Before this he had been doing what so many other cultural scientists have done, namely, he had been conceptualizing what he saw in his terms rather than theirs. This is but Sorokin's point, proved over again quite independently in the science of anthropology. Even a so-called primitive people devoid of a written literature order their relations in terms of their conceptual meanings. Moreover Kluckhohn was able to formulate their legal norms and found them to derive from their philosophy.

But how can philosophy have this basic significance? Is not the response to stimuli of sex and hunger basic, with philosophy a mere afterthought? To answer these questions we must turn to the psychologist.

McCulloch and Pitts' Neurologically Trapped Universals. McCulloch and Pitts have noted that ideas would be irrelevant in behavior were the neurons of the human nervous system ordered linearly. Then the firing of the sensory neuron by the stimulus would fire the cortical neurons and in turn the motor neuron. Thus the stimulus alone would determine behavior.

Lorente de Nó has shown, however, that cortical neurons are ordered in a circle to which a sensory neuron comes and from which a motor neuron goes. Suppose the firing of the sensory neuron fires one of the cortical neurons in the circle and that this cortical neuron in turn fires the next neuron in the circle and so on. Then the im-

pulse produced initially by the stimulus firing the sensory neuron will be passed continuously around the circle. But this impulse represents the stimulus that is gone. When something represents something else, it is a symbol. Thus McCulloch and Pitts noted that in the trapped impulses of Lorente de Nó's reverberating cortical circuits one has the neurological correlate of what introspective psychology calls a meaning or a universal.

Suppose there are several such neurally connected circuits with their different trapped representatives of diverse stimuli or environmental facts. Connected meanings give propositions and connected propositions give theories. Suppose also that some trapped impulses representing certain facts in experience (*i.e.*, stimuli) are used to define others. The trapped universals will then be ordered hierarchically in the cortex. Thus the distinction between basic or philosophical concepts and derived, more inductively given, concepts will arise.

Suppose also that this hierarchy of meanings can both effect the firing of one motor neuron and inhibit the firing of another, as McCulloch shows to be the case. Then we see how philosophy not only can, but must, serve as the normative judge and censor of any stimulus striking a sensory neuron, determining what passes over into overt behavior and what does not. Thus, both law and ethics as grounded in the trapped universals placed at the top of the cortical hierarchy because of their capacity to prepare the human organism for any stimuli hitting it, become intelligible. Neurological as well as introspective psychology hereby combine to affirm that behavior is a response not to stimuli alone, but to ideas found to be basic in remembering, describing and integrating the stimuli, and in enabling one to anticipate tomorrow's stimuli. When many people agree on these basic meanings, one has a single culture.

Cultural sociology and anthropology and neurological behavioristic, as well as introspective, psychology converge upon the following conclusion: The way to an effective world law is through philosophical anthropology.

This way involves several steps. First, the basic meanings or philosophy which defines the ordering relation or living law ethos of each major people and culture of the world must be determined. This entails a study of their basic philosophical and religious classics. Second, the corresponding positive law for each philosophically defined living law must be made explicit. Only thus will the operational consequences in practice of a given living law cultural ethos become evident; and this necessitates a study of the legal classics and practices. Third, with this knowledge from philosophical anthropology of the living law and the corresponding positive law of each culture of the world, the international lawyer is then for the first time able to construct an effective world law. He does this following Ehrlich's criterion of effectiveness by formulating it so that as far as possible it draws upon, is rooted in, and corresponds to the vital living law norms, or in other words the philosophy, of all; rather than, as has been the case in the past, merely one of the peoples and cultures of the world.

Clearly the basic principle underlying this more effective world law must be ideological and cultural pluralism. Its ideal must be a symphony of the world's diverse cultures.

References

1. POUND, R. 1949. Toward a new *jus gentium*, in Ideological Differences and World Order. Yale University Press.
2. SOROKIN, P. A. 1937. Social and Cultural Dynamics. American Book Company, N. Y.
3. KLUCKHOHN, C. The philosophy of the Navaho Indians, in Ideological Differences and World Order, *op. cit.*
4. MCCULLOCH, W. S. & W. PITTS. 1943. How we know universals. Bull. of Math. Biophysics. 5: 115.
5. MCCULLOCH, W. S. 1945. A hierarchy of values determined by the topology of nervous nets. Bull. of Math. Biophysics. 7: 89.
6. NORTHROP, F. S. C. Ideological man in his relation to scientifically known natural man, Ch. XIX, Ideological Differences and World Order, *op. cit.*
7. NORTHROP, F. S. C. 1950. Naturalistic and cultural foundations for a more effective international law. Yale Law Journal. Pp. 1430–1450.
8. NORTHROP, F. S. C. 1951. The importance of deductively formulated theory in ethics and social and legal science, in Structure, Method, and Meaning. The Liberal Arts Press, N. Y. Pp. 99–116.

THE GENERAL CIRCULATION OF THE LOWER ATMOSPHERE*

By SVERRE PETTERSSEN†

Introduction. The term general circulation is commonly used by meteorologists to denote the mean or predominant motions of the atmosphere Although the underlying processes are poorly understood, certain features of these motions are fairly well known. In the lowest layers of the atmosphere, for example, the broad features of the mean circulation are characterized by: (a) a belt of relatively low pressure near the equator; (b) a belt of relatively high pressure in subtropical latitudes; (c) a belt of relatively low pressure in the subpolar latitudes; and (d) a cap of relatively high pressure over the poles.

This zonal distribution is most pronounced in the southern hemisphere, which is predominantly occupied by oceans. In the northern hemisphere, there is a marked seasonal variation such that areas of high pressure tend to occupy the cold continents (in winter) and areas of low pressure tend to occupy the warm continents (in summer).

The factors that maintain these circulation systems are well-known. In the first place, the motions of the atmosphere must be driven by the sources of heat and cold. On the other hand, kinetic energy of the motion relative to the earth must be consumed by frictional dissipation, with the result that a steady mean state is reached over a long space of time.

The purpose of this paper is to indicate a mechanism that is capable of explaining the quasi-stationary circulation systems of the lower atmosphere. A more detailed discussion of this problem has been published elsewhere (Pettersen, 1950).

Vorticity Sources and Sinks. The most complete, and possibly also the simplest statement that we can make about the motion of the atmosphere is probably expressed by the well-known circulation theorem of Bjerknes, which we prefer to write in the following form:

$$\frac{dC}{dt} = N + C_F. \tag{1}$$

Here, C is the circulation along a closed physical curve, N is the number of isosteric-isobaric solenoids enclosed by the curve, and C_F is the circulation of the frictional force along the same curve.

For our purpose, it is convenient to introduce vorticity instead of circulation, thus referring all variables in equation 1 to unit areas. Equation 1 may then be written:

$$\frac{\delta Q}{\delta t} + \mathbf{V}\cdot\nabla_A Q + V_n\frac{\delta Q}{\delta n} = S + F - Q\,\mathrm{div}_A\,\mathbf{V}. \tag{2}$$

Here, Q is the vorticity of the absolute motion, V the wind velocity tangent to an area A; V_n the wind component normal to this area, S the number of solenoids in a unit area, F the vorticity of the frictional force, and $\mathrm{div}_A V$ the two-dimensional divergence in the area A.

It is immediately apparent that the terms $V\cdot\nabla_A Q$ and $Q\mathrm{div}_A V$ can be contracted such that:

$$V\cdot\nabla_A Q + Q\mathrm{div}_A V = \mathrm{div}_A(QV)$$

which is the two-dimensional export of vorticity across the boundary of a unit area in the surface A. We shall write this as:

$\mathrm{div}_A(QV)$ = Surface export of vorticity.

It is now convenient to represent the conditions in a surface of constant entropy. For any such surface, we have by definition:

$$S = O.$$

Furthermore, if the mean motion can be regarded as being stationary, we have:

$$\frac{\delta Q}{\delta t} = O.$$

Thus, when we consider regions of the globe where conditions are quasi-stationary, equation 2 may be written:

Surface export of vorticity

$$= F - V_n\frac{\delta Q}{\delta n}. \tag{3}$$

* This paper, illustrated with lantern slides, was presented at the meeting of the Section on November 27, 1951.

† Air Weather Service, U. S. Air Force, Washington, D. C.

If we add to both sides of this equation the term $Q\frac{\delta V_n}{\delta n}$, we obtain the equivalent equation:

Volume export of vorticity

$$= F + Q\frac{\delta V_n}{\delta n}. \quad (4)$$

Equations 3 and 4 describe stationary motion without reference to sources of heat and cold. To introduce the effect of heat and cold sources,

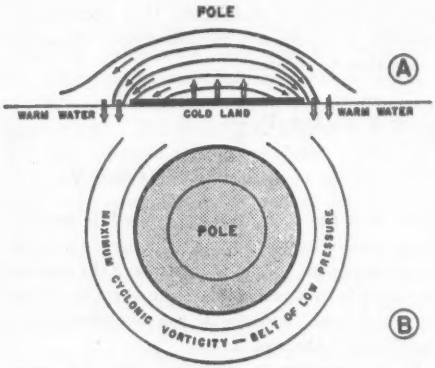


FIGURE 1. (A) Illustrating the export of vorticity along the isentropic sheets from a polar continent; double-shafted arrows indicate transfer of vorticity to and from the earth's surface. (B) Illustrating the resulting pressure field at sea level.

we consider the potential temperature θ. The quantity $d\theta/dt$ is a direct measure of the intensity of the heat supplied to, or withdrawn from, the air. If the motion is to be stationary, we have:

$$\frac{d\theta}{dt} = V_n\frac{\delta\theta}{\delta n} \quad (5)$$

where V_n is the wind component normal to an isentropic surface. Combining this with equation 3, we obtain:

Surface export of vorticity

$$= F - \frac{\delta Q}{\delta\theta}\frac{d\theta}{dt} \quad (6)$$

The left of this equation represents the intensity of the vorticity source. We may speak, therefore, of a frictional component and a thermal component of the vorticity sources and sinks. In the following, we shall apply equation 6 to certain regions of the globe where we are able to determine, at least, the signs of these components.

The Polar Region. Let us first consider a circular continent (or ice field) centered at the pole and surrounded by water of appreciably higher temperature. The isentropic surfaces would then form domes over the cold continent as shown in FIGURE 1.

Any air mass that invades the polar region in winter will be cooled (*i.e.*, $d\theta/dt < 0$), partly through loss of heat to the underlying surface,

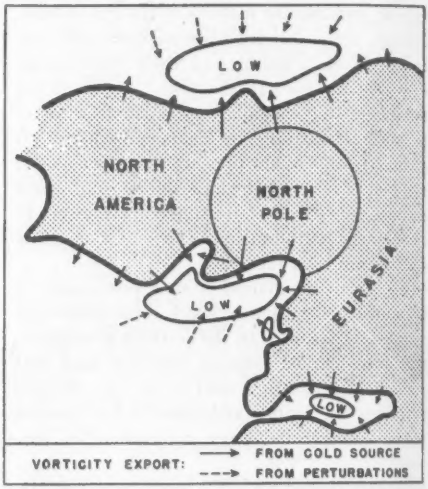


FIGURE 2. Diagrammatic representation of the flux of vorticity from the Arctic icefields and cold continents.

and partly through radiative loss to space. However, since the polar region is surrounded by warmer air, the poleward pressure force must increase with elevation. If the motion is to be predominantly geostrophic, the vorticity must therefore increase with elevation. Hence

$$\delta Q/\delta\theta > 0.$$

It follows that the thermal component of the vorticity source must be positive.

As to the frictional component, it may be noted that the pressure distribution is, on the whole, anticyclonic and so is the vorticity of the motion. If the frictional drag exerted by the earth's surface is to be mainly against the motion of the air, the vorticity of the frictional source must then be cyclonic (*i.e.*, $F > 0$).

It will, thus, be seen that both the frictional and the thermal component of the vorticity source are positive. If vorticity is not to accumulate indefinitely, there must be an export from the

polar cold source, down the slopes of the isentropic surfaces to sea level off the edge of the continent.

If the motion in this coastal belt is to be predominantly geostrophic, then a belt of low pressure must be maintained off the shore of polar continents. The circulation described above is typical of the Antarctic where the continent is fairly symmetrical around the pole.

In the north-polar region the conditions are more complex. Here the northern parts of the North-American and the Eurasian continents act as effective cold sources during the winter season. The isentropic surfaces slope from the interior of these continents downward to the coasts, as well as meridionally from the polar cap, with the result that the exported vorticity must be received by the northern parts of the North-Atlantic and North-Pacific Oceans, as shown in FIGURE 2. In these areas, the air motion is cyclonic, wherefore the vorticity of the frictional force is anticyclonic. Hence, the low pressure areas over the northern oceans constitute the sinks in which the air gives off vorticity to the earth.

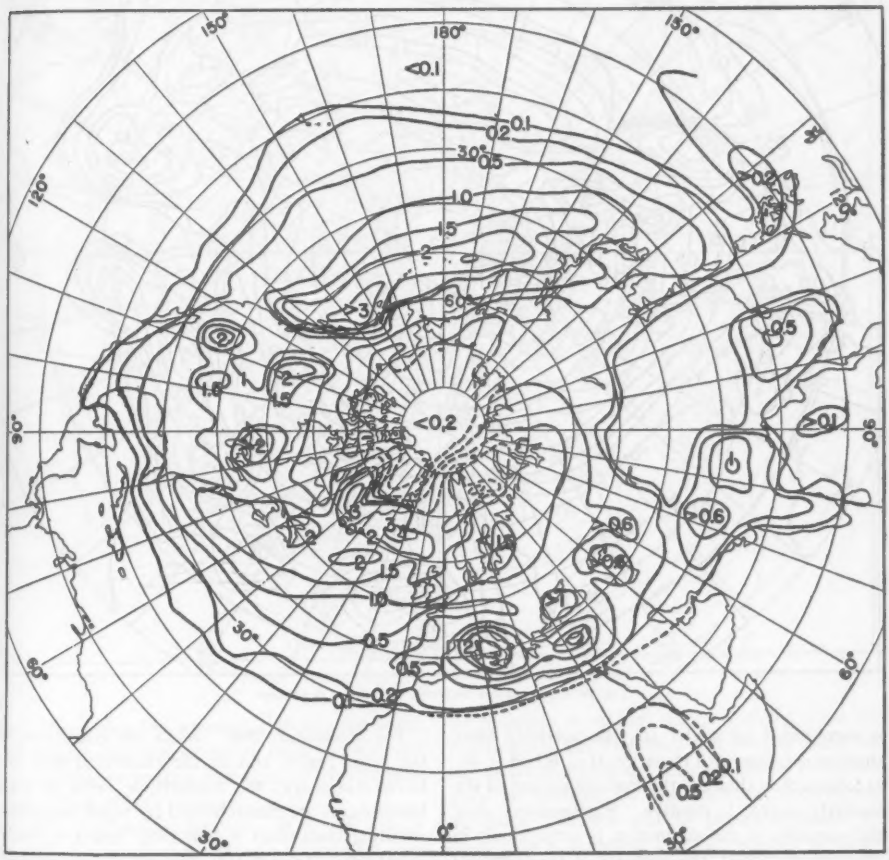


FIGURE 3. Percentage frequency of cyclone centers in winter.

The Trade Wind Belt. In the so-called trade-wind belt, broadly between 5° and 35° latitude in both hemispheres, the conditions are characterized by a remarkably high degree of stationariness. Here, the motion is mainly toward the equator, and the air receives heat from below (*i.e.*, $d\theta/dt > 0$). Since the intertropical belt

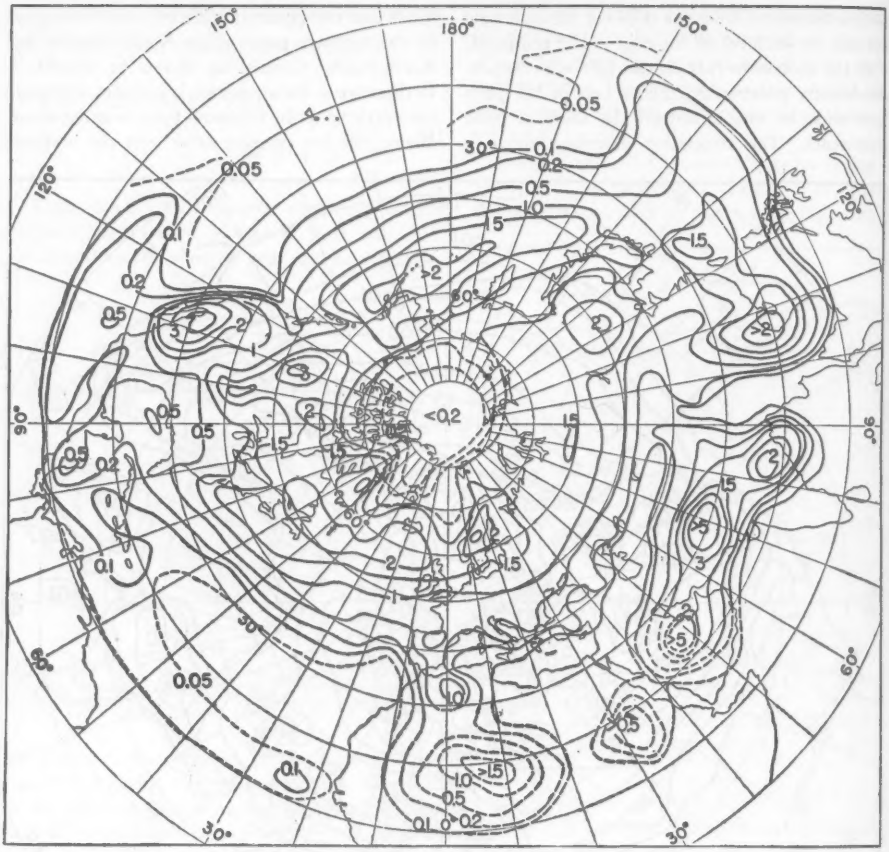


FIGURE 4. Percentage requency of cyclones in summer.

is surrounded by colder air, the vorticity must thereby decrease with elevation (*i.e.*, $\delta Q/\delta\theta < 0$). It follows then that the thermal component of the vorticity source is positive. Furthermore, since the vorticity of the air motion is anticyclonic in the trade-wind belt, the vorticity of the frictional force must be cyclonic (*i.e.*, $F > 0$). Hence, in the trade-wind belt, the frictional and thermal components contribute in the same direction, and to maintain quasi-stationary conditions, vorticity must be exported from both hemispheres to the equatorial belt. On account of this export, the low-pressure areas known as the doldrums and the monsoon systems are maintained.

In these systems the vorticity of the frictional force is negative, and vorticity is steadily surrendered to the surface of the earth.

The Midlatitude Belt. While the conditions in the polar region and in the tradewind belt are fairly stationary, the midlatitude belts of both hemispheres are characterized by rapid variations resulting from what is commonly called dynamic instability. In each belt, we find a succession of travelling cyclones and anticyclones which give rise to rapid fluctuations and alternation between cyclonic and anticyclonic vorticity. It has been shown elsewhere (Petterssen, 1950) that on account of the earth's rotation, the cyclonic systems will have a poleward component of motion, while the anticyclonic systems have an equatorward component. Thus, in the midlatitude belt, there is a tendency toward separation of the vorticity systems, such that the travelling cyclones drift poleward, and contribute toward the maintenance

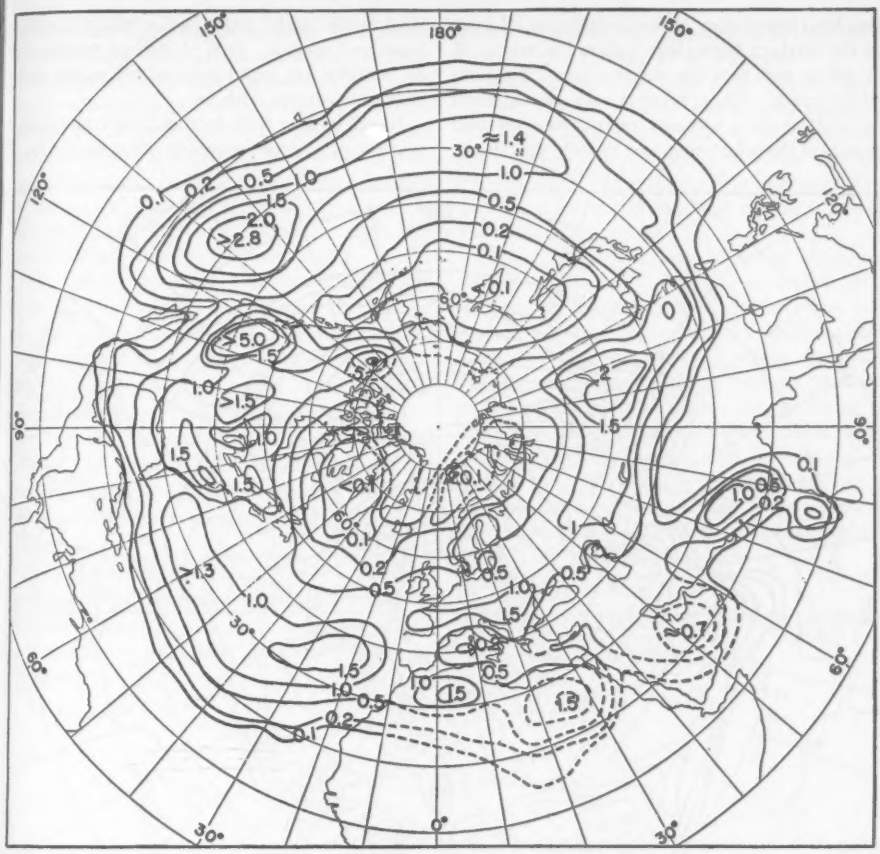


FIGURE 5. Percentage frequency of anticyclones in winter.

of the subpolar low-pressure systems, while the travelling anticyclones tend to drift equatorward and contribute to the maintenance of the subtropical belt of high pressure.

Effect of Mountain Barriers. It is well known from observations that cyclonic circulation systems tend to form to the lee of mountain ranges which are crossed by strong winds. The tendency for this to occur can be demonstrated by reference to equation 4. Neglecting for the moment the vorticity of the frictional force, we have:

$$\text{Volume export of vorticity} = Q\,\frac{\delta V_n}{\delta n}.$$

Normally $\delta V_n/\delta n$ is negative on the windward side and positive to the lee of the barrier. Thus, to maintain a steady state, vorticity must be consumed to the windward and created to the lee of mountain barriers. Although these influences may be modified by the frictional component, statistical evidence will be presented below to show that pronounced vorticity sources occur to the lee of the major mountain ranges.

The Statistical Material. The statistical material presented below has been obtained from the Historical Weather Maps of the U. S. Weather Bureau, which cover the forty-year period 1899–1939, with one map a day. The positions of all cyclonic and anticyclonic centers were evaluated and the frequencies counted for areas of 100,000 sq. km. All in all, the material comprises about 400,000 cyclones and anticyclones.

The Behavior Pattern of Cyclones. The geo-

graphical distribution of the frequency of cyclones in the northern hemisphere is shown in FIGURE 3. It will be seen that the maxima occur along the Arctic coasts. These maxima may be explained as resulting from vorticity export from the cold sources of the polar region and the cold continents, land to the inland water bodies which constitute local heat sources. It is of interest to note that no maxima are found over inland water bodies which are covered with ice.

It will be seen from FIGURE 3 that pronounced maxima of cyclone frequency occur to the lee of

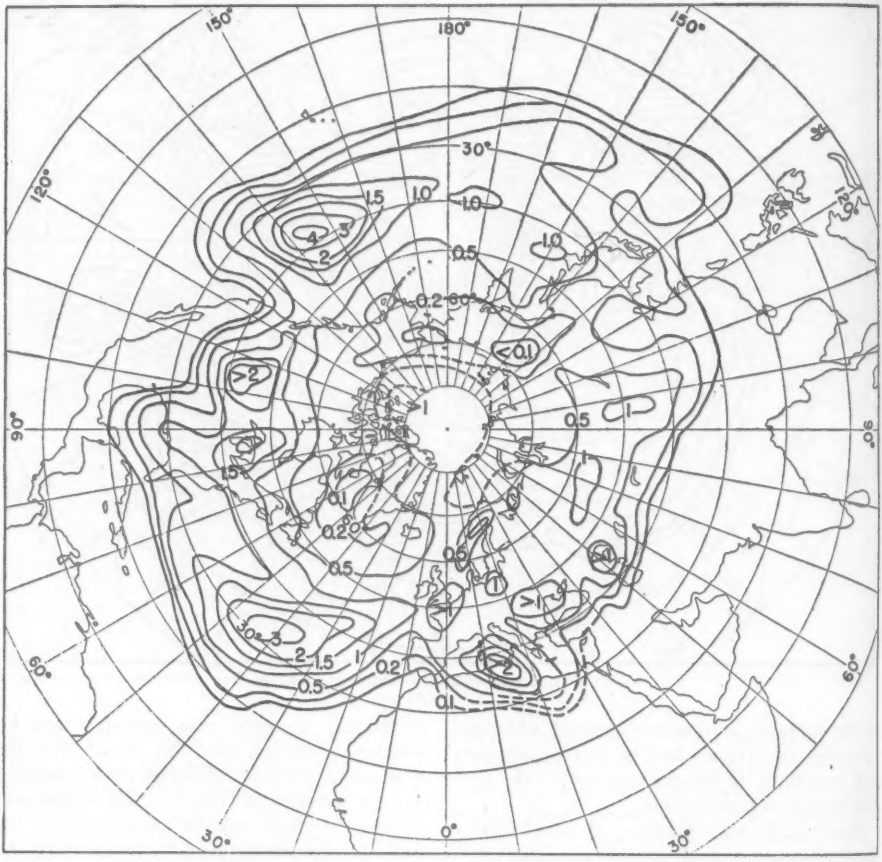


FIGURE 6. Percentage frequency of anticyclones in summer.

to which is added the contribution from the travelling cyclones that drift northward from the midlatitude belt.

In addition to these major maxima, we also find high frequencies over all inland water bodies, such as the Great Lakes, the Baltic, the Mediterranean, the Black Sea, the Caspian Sea and the Aral Sea. These secondary maxima can be explained as resulting from vorticity export from the cold all major mountain ranges which are crossed by the strong westerly winds of the midlatitude belt. Noteworthy are the maxima to the east of the Sierra Nevada, the Colorado, and Alberta ranges, and also to the lee of the Appalachian and the Scandinavian ranges, and similarly situated ranges in East Asia.

The geographical distribution of frequency of cyclones in summer is shown in FIGURE 4. It will

be seen that high frequencies occur in northern latitudes where warm land or warm ocean currents are adjacent to cold ocean currents or ice. As a result, an irregular belt of high frequency extends through the northern parts of the North American and Eurasian continents. It is noteworthy that the inland water bodies (which showed maxima in winter) have minima of cyclone frequency in summer. The effects of mountain ranges are clearly indicated also in the warm season.

The most outstanding difference between the winter and summer seasons is found in relatively low latitudes where vast areas of high cyclonic frequency are found over the warm continents. These maxima, which are known as the monsoon systems, can be explained as a result of export of vorticity from the tradewind belts of both hemispheres. In these systems, the vorticity of the frictional force is negative, indicating that the imported vorticity is surrendered to the earth's surface.

The Behavior Pattern of Anticyclones. The geographical distribution of the frequency of anticyclones is shown in FIGURES 5 and 6 for winter and summer, respectively. A zonal pattern is clearly indicated, with a maximum in about 35°N in winter and in about 45°N in summer.

Superimposed upon this zonal pattern are a number of local maxima and minima associated with such geographical features as mountains, plateaus and lowlands partly or wholly encircled by mountains. It is particularly interesting that the inland water bodies exhibit minima in winter and maxima in summer.

Further Remarks. The foregoing discussion seems to indicate that, although our knowledge of the location and intensity of the heat and cold sources is meager, it is possible on dynamical and thermodynamical principles to explain the broad features of the climatological patterns near the earth's surface. In particular, the occurrence of maxima of cyclone frequency over inland water bodies in the cold season, and the reversal to maxima of anticyclone frequency in the warm season, probably afford the most convincing evidence in support of the theory of vorticity transfer between the heat and cold sources.

Reference

PETTERSSEN, S. 1950. Some aspects of the general circulation of the atmosphere. Centenary Proceedings Roy. Met. Soc. 120–155.

CONFERENCES HELD

SECTION OF PHYSICS AND CHEMISTRY

"MICROWAVE SPECTROSCOPY"
NOVEMBER 9 AND 10, 1951

The Section of Physics and Chemistry held a Conference on "Microwave Spectroscopy." Doctor Benjamin P. Dailey, Columbia University, New York, N. Y. was the Conference Chairman in charge of the meeting.

The program consisted of the following papers:

Friday, November 9

Morning Session.

"Present Status of Microwave Spectroscopy," C. H. Townes, Columbia University, New York, N. Y.

"High Resolution Spectroscopy," S. Geschwind, Columbia University, New York, N. Y.

"Spectroscopy above 40 KMc," Walter Gordy, Duke University, Durham, N. C.

"Spectroscopic Measurements on High-boiling, Reactive, and Unstable Molecules," John Mays, Harvard University, Cambridge, Mass.

"Detection and Measurement of Direct Nuclear Quadrupole Transitions," Ralph Livingston, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Afternoon Session.

"Centrifugal Distortion," M. W. P. Strandberg, Massachusetts Institute of Technology, Cambridge, Mass.

"Microwave Resonance Absorptions in Paramagnetic Gases," Robert Beringer, Yale University, New Haven, Conn.

"Molecular and Nuclear Magnetic Moments," C. K. Jen, Johns Hopkins University, Silver Springs, Md.

"Spectral Lines as Frequency Standards," H. Lyons, Bureau of Standards, Washington, D. C.

Saturday, November 10

Morning Session.

"Chemical Analysis with the Microwave Spectrograph," Richard Highes, Westinghouse Research Laboratory, E. Pittsburgh, Pa.

"Pressure Broadening," William J. Smith, University of Delaware, Newark, Del.

"Spectroscopy of Radioactive Molecules," V. W. Cohen, Brookhaven National Laboratory, Upton, Long Island, N. Y.

"Hindered Rotation," B. P. Dailey, Columbia University, New York, N. Y.

Afternoon Session.

"Significance of the Results of Microwave Spectroscopy to the Theory of Magnetism," J. H. Van Vleck, Harvard University, Cambridge, Mass.

"Significance of the Results of Microwave Spectroscopy to Chemical Valence Theory," E. B. Wilson, Jr., Harvard University, Cambridge, Mass.

"Significance of the Results of Microwave Spectroscopy to Nuclear Theory," Arthur Schawlow, Bell Telephone Laboratory, Murray Hill, N. J.

The Section of Physics and Chemistry provides conferences for active workers in special fields of these subjects.

Attendance is limited to those invited to participate in these Conferences and to interested Members of the Academy.

SECTION OF BIOLOGY

"VIRUSES AS CAUSATIVE AGENTS IN CANCER"
NOVEMBER 16 AND 17, 1951

The Section of Biology held a Conference on "Viruses as Causative Agents in Cancer." Doctor C. P. Rhoads, Director, Memorial Center for Cancer and Allied Diseases, New York, N. Y. was the Conference Chairman in charge of the meeting.

The program consisted of the following papers:

Friday, November 16

Morning Session. "Introductory Remarks." Chairman, C. P. Rhoads

"The Pathogenesis and Pathology of Virus Infections," Henry Pinkerton, St. Louis University School of Medicine, St. Louis, Mo.

"Significance of Cell Particulates as Seen by Electron Microscopy," Keith Porter, University of Washington, Seattle, Wash.

"Cellular Pathology of Virus Infections as Seen with the Electron Microscope," F. B. Bang, The Johns Hopkins University, Baltimore, Md.

"The Enzymes of the Host Cell as a Requirement for Virus Synthesis," Seymour S. Cohen, The Children's Hospital of Philadelphia, Philadelphia, Pa.

"Biochemical Relationship of Viruses with

Cells," E. A. Evans, Jr., University of Chicago, Chicago, Ill.

Afternoon Session. Chairman, John R. Paul.

"Factors Concerned with Viral Proliferation *In Vivo*," Frank L. Horsfall, Jr., The Hospital of the Rockefeller Institute for Medical Research, New York, N. Y.

"Genetic, Hormonal, and Age Factors in Natural Resistance to Certain Viruses," Albert B. Sabin, The Children's Hospital Research Foundation, Cincinnati, Ohio.

"Viruses with Oncolytic Properties and Their Adaptation to Tumors," Alice E. Moore, Sloan-Kettering Institute for Cancer Research, New York, N. Y.

"Immunological Barriers to Viral Growth," Walter Schlesinger, Public Health Research Institute of the City of New York, New York, N. Y.

"Inheritance in Bacteriophage," A. D. Hershey, Carnegie Institution of Washington, Cold Spring Harbor, Long Island, N. Y.

"Latent or Dormant Viral Infections," Hilary Koprowski, Lederle Laboratories Division, American Cyanamid Company, Pearl River, N. Y.

Evening Session. "Biological Studies on Tumors and Viruses," Francisco Duran-Reynals, Yale University School of Medicine, New Haven, Conn.

"Studies on Fowl Lymphomatosis," Ben R. Burmester, U. S. Department of Agriculture, East Lansing, Mich.

"Biological Studies on the Mammary Tumor Inciter in Mice," Howard B. Andervont, National Institutes of Health, Bethesda, Md.

"Observations on the Mouse Mammary Carcinoma Virus," Samuel Graff and Cushman D. Haagensen, City of New York Department of Hospitals, New York, N. Y., and Michael Heidelberger, College of Physicians and Surgeons, Columbia University, New York, N. Y.

"The Significance of Particles in Human Milk," Ludwik Gross and K. S. McCarty, Veterans Administration Hospital, New York, N. Y., and A. E. Gessler, Interchemical Corporation, New York, N. Y.

"Attempts at Tumor Virus Isolation," L. Dmochowski, University of Leeds, Leeds, England.

Saturday, November 17

Morning Session. Chairman, Richard E. Shope.

"Plant Virus Tumors," L. M. Black, Brooklyn Botanic Garden, Brooklyn, N. Y.

"Virus Tumors in Fish," Ross F. Nigrelli, New York Zoological Society, New York, N. Y.

"Kidney Carcinoma in the Leopard Frog: A Virus Tumor," Balduin Lucke, University of Pennsylvania, Philadelphia, Pa.

"Interaction of Tumor Agents and Normal Cellular Components in Amphibia," S. Meryl Rose, Marine Biological Laboratory, Woods Hole, Massachusetts.

"Rabbit Papillomas and the Rabbit Papilloma Virus—A Review," David Ginder, Emory University, Atlanta, Ga.

"The Pathogenesis of the Rabbit Papilloma to Carcinoma Sequence," Jerome T. Syverton, University of Minnesota, Minneapolis, Minn.

"Fibroma-Myxoma Virus Relationship in Rabbit," Margaret H. D. Smith, Tulane University of Louisiana, New Orleans, La.

Afternoon Session. Chairman, C. P. Rhoads.

"Crown-Gall Disease," Armin C. Braun, Rockefeller Institute for Medical Research, New York, N. Y.

"The Status of the Search for a Virus in Hodgkin's Disease," W. L. Bostick, University of California, San Francisco, Calif.

"Production of Neoplasms by Injection of Fractions of Mammalian Neoplasms," Joseph Stasney, A. Cantarow, and Karl E. Paschkis, Jefferson Medical College of Philadelphia, Philadelphia, Pa.

"Mouse Leukemia," Ludwik Gross, Veterans Administration Hospital, New York, N. Y.

"The Transmissible Venereal Tumor of Dogs: Observations on Forty Generations of Experimental Transfers," Alfred G. Karlson and Frank C. Mann, Mayo Foundation, Rochester, Minn.

"Electron Microscopy of Viruses of Human Papilloma, Molluscum Contagiosum, and Vaccinia, Including Observations on the Formation of Virus Within the Cell," Joseph L. Melnick, Henry Bunting, William G. Banfield, Maurice J. Strauss and William H. Gaylord, Yale University School of Medicine, New Haven, Conn.

"Virus-Induced Tumors of Human Skin, (Warts, Molluscum Contagiosum)," Harvey Blank, E. R. Squibb and Sons, New York, N. Y.

"Critical Review of the Subject," H. B. Andervont.

The Section of Biology provides conferences for active workers in the special fields of Biology.

Attendance is limited to those invited to participate in these conferences and to interested Members of the Academy.

"SHOCK SYNDROME"
NOVEMBER 30 AND DECEMBER 1, 1951

The Section of Biology held a Conference on "Shock Syndrome." Doctor John Scudder, The Presbyterian Hospital, Columbia-Presbyterian Medical Center, New York, N. Y. was the Conference Chairman in charge of the meeting.

The program consisted of the following papers:

Friday, November 30

Morning Session. Chairman, Magnus Gregersen.

"Blood Volume," Ernest Basil Gladden Reeve, Clinical Research Unit, Guy's Hospital, London, England.

"Studies on the Coronary Circulation in Man," Richard Bing, The Medical College of Alabama, University of Alabama, Birmingham, Ala.

"Cardiac Output and Arterial and Venous Pressure in Shock," Dickinson Richards, Jr., College of Physicians and Surgeons, Columbia University, New York, N. Y., and Andre Cournand, Columbia-Bellevue Medical Center, New York, N. Y.

"The Terminal Vascular Bed in Experimental Shock," Benjamin Zweifach, Cornell Medical School, New York, N. Y.

Afternoon Session. Chairman, Vincent P. Dole.

"The Significance of the Metabolic Changes During Shock," Frank Engel, Duke Hospital, Durham, North Carolina.

"The Effect of Shock on the Kidney," Howard Eder, New York Hospital, New York, N. Y.

"The Role of Bacteria Infection in Shock," Jacob Fine, Beth Israel Hospital, Boston, Mass.

"The Possible Role of the Adrenal Cortex in Fluid Shifts in the Hamster Following Renal Damage," Frederic J. Agate, Jr., College of Physicians and Surgeons, Columbia University, New York, N. Y.

"Summary of Electrolyte and Water Balance Changes in Shock Due to Hemorrhage or Trauma," Henry Randall, Memorial Center for Cancer and Allied Diseases, and Cornell University Medical School, New York, N. Y.

Evening Session

"The Role of Intra-arterial Transfusion in the Correction of Circulatory Volume Disparity," Sam F. Seeley, Brigadier General, U. S. Army, Walter Reed Hospital, Washington, D. C.

Saturday, December 1

Morning Session. Chairman, Theodore Shedlovsky.

"Capillary Permeability—Pore Size," John Pappenheimer, Harvard Medical School, Cambridge, Mass.

"The Antigenicity of Plasma Substitutes," Michael Heidelberger, College of Physicians and Surgeons, Columbia University, New York, N. Y.

"Production of Precipitins and Cutaneous Sensitivity in Man by Injection of Small Amounts of Dextran," Alvin A. Kabat and Deborah Berg, Departments of Neurology and Bacteriology, College of Physicians and Surgeons, Columbia University and the Neurological Institute, Presbyterian Hospital, New York, N. Y.

"The Serological Activity of Dextrans," Edward J. Hehre and James M. Neill, Cornell Medical School, New York, N. Y.

"The Fate and Disposal of Plasma Substitutes—(Studies with Isotopes)," Frank Hartman, Henry Ford Hospital, Detroit, Mich., and Donald Van Slyke, Brookhaven National Laboratory, Upton, N. Y.

"Some Physical Chemical Aspects of 'Plasma Extenders'," George Scatchard, Massachusetts Institute of Technology, Cambridge, Mass.

Afternoon Session. Chairman, John Scudder.

"An Animal Survival Method for the Evaluation of Agents Designed to Restore Plasma Volume," William M. Govier and George C. Colovos, The Upjohn Company, Kalamazoo, Mich.

"Various Plasma Extenders in Animals," Harry M. Vars, University of Pennsylvania, School of Medicine, Philadelphia, Pa.

"Various Plasma Extenders in Man," Jonathan Rhoads, University of Pennsylvania, School of Medicine, Philadelphia, Pa.

"The Use of Modified Human Globin," Max Strumia, University of Pennsylvania, Philadelphia, Pa.

"Cold Sterilization by Electron Beam as a Possible Tool for the Inactivation of the Virus of Homologous Serum Jaundice in Plasma," Wolfgang Huber, Electronized Chemicals Corporation, Brooklyn, New York.

"The Use of Plasma Volume Extenders in the Armed Forces—Experimental Work," Colonel William H. Amspacher, M. C., Brooke Army Hospital, Fort Sam Houston, Texas.

"The Use of Whole Blood, Blood Plasma and Plasma Expanders by the Armed Forces," Lt. Col. Arthur J. Carbonell, M. C., U. S. Army and Armed Services Blood and Blood Derivatives Group, Walter Reed Hospital, Washington, D. C., and Colonel Douglas B. Kendrick, Jr., M. C., Walter Reed Hospital, Washington, D. C.

NEW MEMBERS

Elected November 15, 1951

SUSTAINING MEMBERSHIP

Tarlov, I. M., M.D., Neurology. Prof. of Neurology, N. Y. Med. Coll., New York, N. Y.

ACTIVE MEMBERSHIP

Allen, Emma G., M.Sc., Virology. Res. Assist., Children's Hosp., Philadelphia, Pa.

Ajzenberg, M. A., M.S., Maths., & Engineering. President, Intl. Fermont Machinery, New York, N. Y.

Ark, Peter Alexander, Ph.D., Bacterial Disease., Assoc. Prof. of Plant Pathology, Univ. of Cal., Berkeley, Cal.

Avery, James K., D.D.S., Dental Anatomy. Univ. of Rochester, N. Y.

Bennett, H. Stanley, M.D., Cytochemistry. Exec. Officer, Prof. of Anatomy, Univ. of Washington, Seattle, Wash.

Brown, Arthur A., Ph.D., Mathematics. Deputy Director, Operations Eval. Group, Mass. Inst. of Technology, Alexandria, Va.

Canarile, Leonard, B.S., Medical Bacteriology. Med. Bacteriologist, State Univ. of N. Y., Syracuse, N. Y.

Chang, Min- Chueh, Ph.D., Physiology of Reproduction. Res. Assoc., Worcester, Foundation, Shrewsbury, Mass.

Chase, Herman B., Ph.D., Physiological Genetics. Assoc. Prof. Of Biology, Brown Univ., Providence, R. I.

De Seversky, Alexander P., D.Sc., Mathematics & Engineering. Pres. Republic Aviation Co., New York, N. Y.

Deuber, Carl G., Ph.D., Microbiology, Director, Deuber Labs., New York, N. Y.

Ellis, Charles Herbert, Ph.D., Pharmacology. Senior Pharmacologist, Wellcome Res. Labs., Tuckahoe, N. Y.

Gamow, George, Ph.D., Physics, Maths., Engineering. Professor, George Washington Univ., Bethesda, Md.

Grossman, Henry Earle, D.V.M., Vet. Medicine. Brooklyn, N. Y.

Gustin, John C., Psychology. Consulting Psychologist, New York, N. Y.

Horning, Evan C., Ph.D., Pharmaceutical Chemistry. Chief, Sect. on Chemistry of Ntl. Products, Ntl. Heart Inst., Bethesda, Md.

Jacobs, George J., M.Sc., Hematology, Physiology. Biologist, Naval Med. Res. Inst., Bethesda, Md.

Kahn, Bernard S., M.D., Hematology. Assoc. Hematologist, Lebanon Hosp., New York, N. Y.

Kalter, Henry H., M.D., Internal Medicine. Lecturer, Dept. of Int. Med., N. Y. Polyclinic Med. School, New York, N. Y.

Kavaljian, Leroy G., Ph.D., Plant Pathology. Res. Assoc., Brooklyn Botanic Garden, Brooklyn, N. Y.

Klaunberg, Henry J., Ph.D., Medicine. President, Wash. Inst. of Med., Washington, D. C.

Kunnas, Eric, Jr., B.Ch.E., Pharmaceutical Chem. Director of Res. & Production, Holland, Rantos Co., Inc., Trenton, N. J.

Loomis, Ladd N., D.V.M., Virus Pathology. SA Veterinarian, Ntl. Insts. of Health, Bethesda, Md.

May, Paul S., B.S., Microbiology. Grad. Student, Syracuse Univ., Syracuse, N. Y.

May, Robert Elliot, M.S., Endocrinology. Res. Assist. Univ. of Illinois, Urbana, Illinois.

Nakashima, Ritsu, B.A., Hematology. Res. Technician, Merck Inst., New York, N. Y.

Noe, Joseph T., M.D., Industrial Med., Med. Director, East Liverpool Potteries, Chester, West Va.

O'Brien, S. James, Ph.D., Physical Chemistry. Res. Chemist, American Cyanamid Co., Bound Brook, N. J.

Penny, Stanley G., D.V.M., Vet. Medicine. Brooklyn, N. Y.

Rumery, Ruth E., M.S., Nutritional Pathology. Grad. Res. Fellow, Dept. of Anatomy, Univ. of Rochester, Rochester, N. Y.

Safadi, David, M.D., Human Pathology. Res. Pathologist, Kings County Hosp., Brooklyn, N. Y.

Sokalchuk, Andrew, M.D., Medical Physiology. Res. Physiologist, Smith, Kline & French Labs., Philadelphia, Pa.

Strangio, Vincent J., D.O., Medicine, Psychiatry. Osteopathic Physician, Michigan City, Ind.

Sykes, Marguerite P., M.D., Neoplastic Disease. Memorial Hosp., New York, N. Y.

Taft, Clarence B., B.A., Med. & Biological Sciences. Director of Product Develop., Schenley Labs., New York, N. Y.

Taran, Leo M., M.D., Medicine. Pediatric Cardiologist, New York, N. Y.

Taylor, Jr., Howard C., M.D., Medicine. Prof. & Chairman of Dept. of Obstetrics, Columbia Univ., New York, N. Y.

Taylor, Walter A., Ph.D., Chemistry, Mgr. Res. & Control Labs., Pond's Extract Co., Clinton, Conn.

Tenney, Vivien A. M.D., Medicine. Private Practice, New York, N. Y.

Taube, Norman, M.D., Endocrinology. New York, N. Y.

Tuthill, Dorothy D., Ph.D., Psychology. Clin. Psychologist, V. A. Regional Office, New York, N. Y.

West, William T., B.A., Biology. Grad. Res. Fellow in Anatomy, Univ. of Rochester, Rochester, N. Y.

Wolken, Jerome J., Ph.D., Biophysics. Visiting Res Fellow, Rockefeller Inst. of Med. Res., New York N. Y.

STUDENT MEMBERSHIP

Stambler, Moses, Psychology. Student, New School, New York, N. Y.